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Essays on Fiscal Policy and Productivity Growth

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Dissertation

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Abstract

The unifying theme of this dissertation is economic growth in a broad sense. On one hand, economic growth is influenced by productivity growth that has economic consequences for converging economies, which gradually catchup to those that are more advanced. On the other hand, economic growth is influenced by fiscal policy, more specifically by government decisions about taxes and government expenditure. This dissertation consists of three separate chapters.

In the first chapter, I focus on the Balassa-Samuelson (henceforth B-S) effect in the context of the convergence of the Czech Republic to the Euro Area. The B-S effect implies that highly productive countries have higher inflation and appreciating real exchange rates because of larger productivity growth differentials between tradable and nontradable sectors relative to advanced economies. The B-S effect may pose a threat to converging European countries that would like to adopt the Euro because of the limits imposed on inflation and nominal exchange rate movements by the Maastricht criteria. Thus, the main goal of this study is to determine whether the B-S effect is a relevant issue for the Czech Republic in complying with selected Maastricht criteria before adopting the Euro. For this purpose, I build and estimate a two-sector DSGE model of a small open economy. The simulations from the model suggest that the B-S effect is not an issue for the Czech Republic when meeting the inflation and nominal exchange rate criteria. The costs of early adoption of the Euro are not large in terms of additional inflation pressures, which materialize mainly after the adoption of the single currency. In addition, nominal exchange rate appreciation, driven by the B-S effect, does not breach the limit imposed by the ERM II mechanism.

In the second chapter, I build a structural fiscal DSGE model to address four important issues of Czech fiscal policy. 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). I use fiscal multipliers to derive the appropriate composition of growth-friendly fiscal strategies, e.g., I determine that 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. In addition to the output effects, I also evaluate welfare effects of different fiscal stimuli. Furthermore, I show that fiscal devaluation can boost real GDP growth by 0.5 percentage points in the first year, when a

budget-neutral tax shift of the magnitude of 1% of GDP occurs from direct to indirect taxes. These results corroborate the view that the government can easily support the economy by appropriately adjusting fiscal instruments.

In the third chapter, I address past fiscal discretion in the Czech Republic. I find that fiscal discretion in the Czech Republic was used frequently, and that some sizeable impacts on real GDP growth have been recorded, particularly in years 2004, 2009, and 2016, with estimated impacts reaching about 1.0–1.5 p.p. in real GDP growth. Further, I find that fiscal discretion in the Czech Republic was pro-cyclical in years 2008, 2010, 2012–2013, and 2016–2017, whereas it was counter-cyclical in 2009, 2011, and 2014–2015. A clear link between fiscal discretion and the business cycle cannot be distinguished, suggesting that, on average, Czech fiscal discretion has not contributed to stabilizing business cycle fluctuations. Finally, if past fiscal discretion in the Czech Republic had had a better growth-friendly composition, as was proposed by fiscal strategies in the second chapter of this dissertation, then real GDP could have grown faster by approximately 1.8 pp in cumulative terms over the 2001–2017 period.

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Robert Ambrisko

Chapter 1

A Small Open Economy with the Balassa-Samuelson Effect[1]

1.1 Introduction

The Balassa-Samuelson (B-S) effect originated more than a half century ago in the works by Balassa (1964) and Samuelson (1964), and is based on differential productivity growth in tradable and nontradable production sectors. The B-S effect implies that highly productive countries have higher inflation and appreciating real exchange rates because of larger productivity growth differentials between tradable and nontradable sectors relative to advanced economies. This is particularly important for new member countries of the European Union (EU), including the Czech Republic, in which a catch-up process with advanced European countries is still ongoing.

The productivity[2] growth differential between the Czech Republic and the Euro Area has risen from the beginning of 2000 until the end of 2019 by more than 40%, which is displayed in Figure 1.2 in the Appendix. At the same time, the inflation differential, expressed as the difference between normalized HICP indexes for these two economies, widened to approximately 10% (see Figure 1.3), while the real exchange rate[3] between

[1]This chapter is an updated and extended version of Ambriško (2015): "A Small Open Economy with the Balassa-Samuelson Effect" CERGE-EI Working Papers wp547. I am grateful to Michal Kejak, Nurbek Jenish, Byeongju Jeong, Jan Kmenta, and Sergey Slobodyan for their help and valuable comments. The financial support of the Czech Science Foundation project No. P402/12/G097 DYME Dynamic Models in Economics is acknowledged.

[2]Measured as real labour productivity per hour worked.

[3]The real exchange rate is calculated from the nominal exchange rate, which is multiplied by the

the Czech Crown and the Euro appreciated by more than 30% (Figure 1.4).

At some point, the Czech Republic is obliged to adopt the Euro as a single currency. Prior to adopting the Euro, the so-called the Maastricht convergence criteria have to be met, which include: the inflation rate criterion, the nominal interest rate criterion, the nominal exchange rate criterion, and fiscal criteria.[4] If the presence of the B-S effect is relevant for a country, occurring through higher inflation pressures and appreciation of its currency, then some criteria might not be met. This concerns mainly the inflation, interest rate and exchange rate criteria. In other words, the ongoing convergence process, measured by excessive productivity growth with respect to the rest of the EU, might restrain a country from complying with the Maastricht criteria.

The mainstream literature has predominately focused on the magnitude, causes and consequences of the B-S effect within non-optimizing frameworks[5]. There are some exceptions that build dynamic stochastic general equilibrium (DSGE) models for European accession countries, which do address the implications of the B-S effect on the ability of converging countries to satisfy the Maastricht criteria. For instance, Ravenna and Natalucci (2008) construct a two-sector DSGE model for the Czech Republic, and conclude that in the presence of the B-S effect there is no monetary policy that would allow for the fulfillment of both nominal exchange rate criterion and the inflation rate criterion. Masten (2008) builds a simpler two-sector DSGE model calibrated for the Czech Republic, and finds that the B-S effect is not a threat to fulfilling the inflation rate criterion when monetary policy is committed to an inflation objective. Given that the evidence seems to be mixed, at least for the Czech Republic, this study contributes to the debate and evaluates the ability of the Czech Republic to meet the Maastricht criteria with Euro adoption. An additional contribution of this study is that it simulates a transition from a flexible to a fixed exchange rate regime in the context of the B-S effect.

Specifically, the following questions are addressed: What is an appropriate time for a converging country to enter the Euro Area (EA)? Should it wait until the B-S effect

ratio of HICP indexes in the Euro Area and the Czech Republic, and consequently normalized to the beginning of the period displayed.

[4]Specifically, the annual inflation rate must not exceed the average of the three countries in the Euro Area with the lowest inflation by more than 1.5 percentage points. The average long-term interest rate must not exceed the long-term interest rates in the three countries in the Euro Area with the lowest inflation by more than 2 percentage points. The country has to participate in the European Exchange Rate Mechanism (ERM II) for at least two years, which requires limited movements of the exchange rate against the Euro (+/-15%), without devaluating its currency. Fiscal criteria restrict general government debt and deficit below 60% and 3% of GDP, respectively.

[5]See for example Mihaljek and Klau (2004), Égert, Halpern, and MacDonald (2006) and related references therein.

dissipates over time and join the EA subsequently? Is early adoption of the Euro wrong? If a country decides to enter the EA early, what are the inflation costs due to the ongoing transition process? What is the extent of exchange rate appreciation that is induced by the productivity growth differential between the Czech Republic and the EA?

To answer these questions, I build a two-sector DSGE model of a small open economy which is estimated for the Czech Republic. The model draws mainly from Ravenna and Natalucci (2008), but to be more realistic, it is extended by several dimensions, including the following: i) the model is estimated on Czech data using Bayesian techniques, ii) wages are set in staggered contracts, iii) habits in consumption are allowed, iv) productivity growth can be permanent, and v) the inflation target can be non-zero. The main features of my model, including comparison to the works by Ravenna and Natalucci (2008) and Masten (2008), are summarised in Table 1.3 in the Appendix.

The simulations from the model show that the B-S effect is not a relevant issue for the Czech Republic in meeting the Maastricht convergence criteria before adopting the Euro. The costs of early adoption are not large in terms of additional inflation pressures which materialize after adoption of the single currency. Specifically, early transition is associated with initially higher inflation, rising by some 0.4 percentage points in the first year after adoption of the Euro. In addition, nominal exchange rate appreciation, driven by the B-S effect, does not breach the limit imposed by the ERM II mechanism.

My main conclusions regarding the ability of the Czech Republic to fulfill the Maastricht criteria, vary from those of Ravenna and Natalucci (2008), which can be explained by the following reasons: i) the different calibration and structure of my model, ii) my results, similar to Masten (2008), are based on a relatively simple analysis of impulse response functions, whereas Ravenna and Natalucci (2008) rely on more sophisticated tools, namely probability and welfare analysis, to derive their policy implications.

The remainder of the first chapter is organized as follows. Section 2 reviews relevant literature concerning the B-S effect. Section 3 presents the model, the data used, and the model calibration and estimation. Section 4 provides the results of the simulations from the model and robustness tests. The last section summarizes findings and outlines possible directions for future research.

1.2 Relevant Literature with the B-S Effect

There is a growing number of papers that empirically investigate the extent of the B-S effect for the countries of Central and Eastern Europe (CEE). Older studies based on data from the 1990s estimated sizeable contributions of the B-S effect on inflation rates for CEE countries, whereas recent literature finds the impact of the B-S effect on inflation differentials between the new EU member countries and the EA in the range of 0 to 2 percentage points annually (Égert 2011; Konopczak 2013; Mihaljek and Klau 2008; Miletic 2012).[6] Several reasons may explain why the impact of the B-S effect on inflation differential is found to be relatively small. The large share of food items and the low share of nontradables in the consumer price index (CPI) may attenuate the extent of the B-S effect (Égert et al. 2003). Further, a large proportion of administrated and regulated prices in the CPI can account for an important share of excess inflation (Cihak and Holub 2003). The small extent of the B-S effect can also be attributable to the fact that purchasing power parity (PPP) may not hold for tradable goods, since many prices of tradable goods involve some nontradable components, such as rent, distribution services, advertising, etc.

The discussion in the literature focuses somewhat less on the implications of the B-S effect in the DSGE-type models. Two relevant contributions were mentioned in the introduction (Ravenna and Natalucci 2008; Masten 2008), which address the consequences of the B-S effect on the ability of the Czech Republic to meet the Maastricht criteria. Masten (2008) criticizes Ravenna and Natalucci (2008) for an inappropriate simulation of the B-S effect, in which a stationary productivity process in the tradable sector is set so as to deliver the desired increasing productivity path. He argues that one should simulate the B-S effect with permanent nonstationary productivity shocks, and he proceeds in this manner in his paper; nonetheless, the main concern about the model in Masten (2008) is the assumption of exogenous externality in production costs. This feature turned out to be crucial to mimic the theoretical predictions of the B-S effect, but it lacks any microeconomic foundations. Table 1.3 in the Appendix provides a closer view of the models used in these two papers, also compared against the model developed in this study.

Further, Devereux (2003) develops a DSGE of a small open economy to examine the

[6] One explanation can stem from the fact that the productivity differential has stalled during the more recent period. For instance, see Figure 1.2 in the Appendix for the productivity differential between the Czech Republic and the Euro Area.

adjustment process following EU accession in the presence of capital inflow and productivity shocks. He identifies the following transition problems after adopting the Euro: large foreign borrowing, high wage inflation, and excessive growth on the stock market and in the nontradable sector. However, these inefficiencies can be overcome by the application of alternative monetary policies. In particular, the policy of flexible inflation targeting with weight on exchange rate stability seems the best. Laxton and Pesenti (2003) build a DSGE model of large complexity to assess the effectiveness of the alternative Taylor rules in stabilizing variability in output and inflation. Their model is calibrated for the Czech Republic, and the authors find that inflation-forecast-based rules perform better than conventional Taylor rules.

In her DSGE model calibrated for the Czech Republic, Lipinska (2008) analyzes the convergence criteria that are not satisfied when monetary policy is conducted optimally. The author finds that optimal monetary policy violates the inflation rate criterion and the nominal interest rate criterion. Moreover, she compares the welfare costs when optimal monetary policy is unconstrained with the case in which monetary policy is constrained by the Maastricht convergence criteria. The results indicate that constrained monetary policy accounts for additional welfare costs of up to 30% of the deadweight loss associated with the optimal unconstrained monetary policy.

Ghironi and Melitz (2005) provide an endogenous microfounded explanation for the B-S effect in response to productivity shocks. In their two-country DSGE model, the firms differ in productivity and face sunk entry cost and export costs. This suggests that only sufficiently productive firms enter the foreign market, and thus some of the goods will remain nontraded. This is the feature of endogenous nontradedness which evolves over time in relation to productivity growth. The outcome of the model is consistent with the B-S effect; that is, more productive countries are associated with higher average prices and with appreciating real exchange rates.

In his DSGE model, Sadeq (2008) compares estimated structural shocks and impulse responses to permanent tradable productivity shocks across five accession countries. In the case of the Czech Republic, he identifies a risk premium shock to be volatile, but finds that impulse responses to tradable shocks are less volatile compared to other countries in the sample. Rabanal (2009) estimates a DSGE model of a currency union to explain the sources of inflation differentials between the EA and Spain, and concludes that the B–S effect does not seem to be an important driver of the inflation differential.

1.3 Structural DSGE Model

The model I develop in this study is based on Ravenna and Natalucci (2008), enriched with several extensions. A small open economy is populated by monopolistically competitive households, which provide differentiated labor services to an employment agency. The employment agency distributes labor services to the firms in the nontradable and tradable sectors, according to their demand. Labor is perfectly mobile across the two sectors, and the wages are set in staggered contracts. The firms in the nontradable sector are monopolistically competitive, and adjust their prices in the manner of Calvo (1983), whereas the firms in the tradable sector are perfectly competitive. By renting capital, the firms face adjustment costs. The investment goods are composed from tradable, nontradable and foreign inputs. Tradable firms are allowed to use foreign inputs in their production. Notice that foreign goods implicitly enter nontradable production as well through capital accumulation. The labor-augmenting productivity for tradable and nontradable firms can differ, which enables the simulation of the B-S effect.

The value added of this model compared to Ravenna and Natalucci (2008) is that it includes several more realistic features: i) the model is estimated on Czech data using Bayesian techniques, ii) wages are set in staggered contracts, iii) habits in consumption are allowed, iv) productivity growth can be permanent (balanced growth path model), and v) the inflation target can be non-zero. The features of the model are shown in Figure 2.1, where the green parts depict the flows in the tradable sector, and the red parts represent the flows in the nontradable sector.

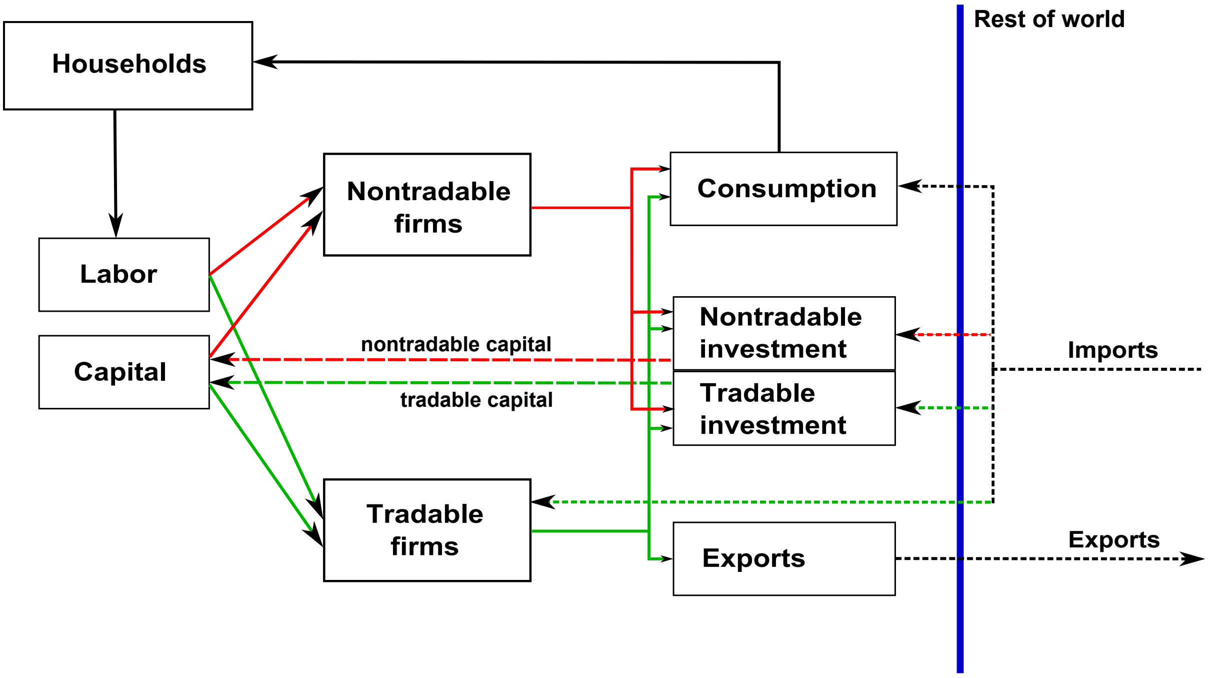
1.3.1 Households

The economy is populated by a continuum of monopolistically competitive households, indexed by $i \in [0, 1]$. Each household supplies a differentiated labor service to the firms, and maximizes its lifetime utility function given by:

$$U(i) = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ D_t \log \left[C_t(i) - \chi_c C_{t-1}(i) \right] - l \frac{\left[L_t^s(i) \right]^{1+\eta_L}}{1+\eta_L} \right\}, \tag{1.1}$$

in which β is a discount factor, χ_c is a consumption habit parameter, D_t is an exogenous preference shock, η_L is the inverse of the labor supply elasticity, l is the parameter measuring relative disutility of labor supply, $C_t(i)$ and $L_t^s(i)$ are consumption and labor supply of household i. Assuming perfect substitution between hours worked in nontradable and

Figure 1.1: The Scheme of the Model



tradable sectors, aggregate labor supply equals:

$$L_t^s = L_t^N + L_t^H \tag{1.2}$$

Total consumption is a constant elasticity of the substitution (CES) composite index of nontradable and tradable consumption goods:

$$C_t = \left[(\gamma_n)^{\frac{1}{\rho_N}} (C_{N,t})^{\frac{\rho_N - 1}{\rho_N}} + (1-\gamma_n)^{\frac{1}{\rho_N}} (C_{T,t})^{\frac{\rho_N - 1}{\rho_N}} \right]^{\frac{\rho_N}{\rho_N - 1}}, \tag{1.3}$$

in which $0 \leq \gamma_n \leq 1$ is the share of nontradables in consumption, and $\rho_N > 0$ is the elasticity of substitution between nontradable and tradable consumption goods. The tradable consumption good is a CES composite of home and foreign tradable goods:

$$C_{T,t} = \left[(\gamma_h)^{\frac{1}{\rho_H}} (C_{H,t})^{\frac{\rho_H - 1}{\rho_H}} + (1-\gamma_h)^{\frac{1}{\rho_H}} (C_{F,t})^{\frac{\rho_H - 1}{\rho_H}} \right]^{\frac{\rho_H}{\rho_H - 1}}, \tag{1.4}$$

in which $0 \leq \gamma_h \leq 1$ is the share of domestic tradable goods in tradable consumption, and $\rho_H > 0$ is the elasticity of substitution between domestic and foreign consumption goods.[7]

[7]The posterior estimate of this elasticity turned out to be flat (see Figure 1.5), which suggests that

The nontradable consumption good is an aggregate over a continuum of differentiated goods:

$$C_{N,t} = \left[\int_0^1 (C_{N,t})^{\frac{\epsilon_N - 1}{\epsilon_N}} (z) dz \right]^{\frac{\epsilon_N}{\epsilon_N - 1}} \tag{1.5}$$

in which the elasticity between nontradable good varieties is $\epsilon_N > 1$ and $z \in [0, 1]$.

Based on the above preferences, it is possible to derive consumption-based price indices:

$$P_t = \left[\gamma_n (P_{N,t})^{1-\rho_N} + (1 - \gamma_n) (P_{H,t})^{1-\rho_N} \right]^{\frac{1}{1-\rho_N}} \tag{1.6}$$

$$P_{N,t} = \left[\int_0^1 (P_{N,t})^{1-\epsilon_N} (z) dz \right]^{\frac{1}{1-\epsilon_N}} \tag{1.7}$$

in which P_t, and $P_{N,t}$ are the consumer price index (CPI), and the price index for nontradable consumption goods. It is assumed that the price of tradable goods is determined abroad, and the law of one price holds for tradable goods, and the exchange rate pass-through is complete.[8] Thus, the price for tradable goods is given as:

$$P_{H,t} = ER_t P_t^*, \tag{1.8}$$

in which P_t^* is the exogenous foreign-currency price of the tradable good, and ER_t is the nominal exchange rate, which is expressed as the value of foreign currency in units of domestic currency. Investments in the nontradable and domestic tradable sector are defined similarly as consumption aggregates:

$$I_t^J = \left[(\gamma_n)^{\frac{1}{\rho_N}} \left(I_{N,t}^J \right)^{\frac{\rho_N - 1}{\rho_N}} + (1 - \gamma_n)^{\frac{1}{\rho_N}} \left(I_{T,t}^J \right)^{\frac{\rho_N - 1}{\rho_N}} \right]^{\frac{\rho_N}{\rho_N - 1}} \tag{1.9}$$

$$I_{T,t}^J = \left[(\gamma_h)^{\frac{1}{\rho_H}} \left(I_{H,t}^J \right)^{\frac{\rho_H - 1}{\rho_H}} + (1 - \gamma_h)^{\frac{1}{\rho_H}} \left(I_{F,t}^J \right)^{\frac{\rho_H - 1}{\rho_H}} \right]^{\frac{\rho_H}{\rho_H - 1}} \tag{1.10}$$

tradable aggregation may be simplified, for instance using Cobb-Douglas specification.

[8] Ravenna and Natalucci (2008) also tried the specification with local currency pricing for foreign-produced goods. Its impact on the dynamics of aggregate variables following the B-S shock was limited, which may be explained by the low share of foreign goods in tradable baskets. To some extent, the assumption of perfect competition in the tradable sector might be responsible for the relatively benign results in my analysis.

$$I_{N,t}^{J}=\left[\int_{0}^{1}(I_{N,t}^{J})^{\frac{\epsilon_N}{\epsilon_N-1}}(z)dz\right]^{\frac{\epsilon_N}{\epsilon_N-1}},\ J=N,H \tag{1.11}$$

The superscript J refers to the nontradable and tradable sector. By specification, investment price indices coincide with consumption price indices counterparts.

The households possess physical capital and rent it to the firms. Capital is sector-specific, e.g. it is assumed to be immobile between the tradable and nontradable sectors. The capital in both sectors depreciates at a common constant rate $\delta > 0$. To avoid possible excessive investment volatility, capital is subject to convex adjustment costs. Specifically, the law of the accumulation of capital stocks follows:

$$K_t^J=\Phi\left(\frac{I_t^J}{K_{t-1}^J}\right)K_{t-1}^J+(1-\delta)K_{t-1}^J,\ J=N,H \tag{1.12}$$

in which I_t^J denotes gross investment, and $\Phi(.)$ is an increasing and concave function, which satisfies: $\Phi(\frac{I}{K}A)=\frac{I}{K}A$ and $\Phi'(\frac{I}{K}A)=1$, in which $\frac{I}{K}$ is a steady-state investment-capital ratio and A is a steady-state growth rate of technology. The following functional form for adjustment cost is chosen:

$$\Phi\left(\frac{I_t^J}{K_{t-1}^J}\right)=\phi_0+\phi_1\left(\frac{I_t^J}{K_{t-1}^J}\right)^{\phi_2}, \tag{1.13}$$

in which coefficients ϕ_0,ϕ_1,ϕ_2 are calibrated so as to match desired functional properties.

Households face the following budget constraint:

$$\begin{aligned}P_tC_t+B_t+ER_tB_t^*+P_t\left(I_t^N+I_t^H\right)&=W_t\left(L_t^H+L_t^N\right)+\\&+R_{t-1}B_{t-1}+R_{t-1}^*ER_tB_{t-1}^*+P_{N,t}R_t^NK_{t-1}^N+P_{H,t}R_t^HK_{t-1}^H+\Pi_t\end{aligned} \tag{1.14}$$

in which W_t denotes the nominal wage common in both sectors; B_t, B_t^* holdings of bonds denominated in domestic and foreign currency, R_t, R_t^* domestic and foreign interest rate paid on bonds; R_t^N, R_t^H the real return to capital in the tradable and nontradable sector; and Π_t nominal profits from monopolistically competitive firms. The right-hand side of (1.14) represents households' wealth, that is, income received from supplying labor and renting capital to firms, from interest on bonds, and from firms' profits in the monopolistically competitive nontradable sector. The left-hand side of (1.14) represents the usage of wealth; that is, purchases of consumption and investment goods, or savings in bonds.

1.3.2 Firms

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

$$Y_{N,t}(z) = \left[A_t^N L_t^N(z)\right]^{1-\alpha_n} \left[K_{t-1}^N(z)\right]^{\alpha_n}, \tag{1.15}$$

in which A_t^N is a labor-augmenting technology process in the nontradable sector, and labor input is defined as $L_t^N(z) = (\int_0^1 [L_t^N(z,i)]^{\frac{\epsilon_W - 1}{\epsilon_W}} di)^{\frac{\epsilon_W}{\epsilon_W - 1}}$, in which ϵ_W is the elasticity of substitution for labor services between individual households. Due to common production technology, sector-wide nontradable production equals:

$$\int_0^1 Y_{N,t}(z)dz = \left(A_t^N L_t^N\right)^{1-\alpha_n} \left(K_{t-1}^N\right)^{\alpha_n} \tag{1.16}$$

Nontradable firms minimize the total costs of production $P_{N,t} R_t^N K_{t-1}^N(z) + W_t L_t^N(z) - \tau_N P_{N,t} Y_t^N(z)$, given their production function in (1.15). According to Erceg, Henderson, and Levin (2000) nontradable production is subsidized at a fixed rate τ_N to ensure that the equilibrium would be Pareto optimal if prices were flexible. Cost minimization yields the following factor demands:

$$\begin{aligned} R_t^N &= \alpha_n \frac{Y_t^N}{K_{t-1}^N} (rmcn_t + \tau_N) \\ \frac{W_t}{P_{N,t}} &= (1-\alpha_n) \frac{Y_t^N}{L_t^N} (rmcn_t + \tau_N), \end{aligned} \tag{1.17}$$

in which the firm's index z is omitted because of symmetry, and $rmcn_t$ denotes real marginal costs in the nontradable sector. 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 $1 - \xi_N$. The remaining firms, which are not allowed to optimally adjust their prices in a given period, automatically index prices using the last-known nontradable sector-wide inflation rate $\Pi_{N,t}$ (e.g. $P_{N,t}(z) = P_{N,t-1}(z)\Pi_{N,t-1}$). This pricing implies the following Phillips curve:

$$\log \frac{\Pi_{N,t}}{\Pi_{N,t-1}} = \beta \log \frac{\Pi_{N,t+1}}{\Pi_{N,t}} + \frac{(1-\xi_N)(1-\beta\xi_N)}{\xi_N} \log(rmcn_t \Theta_N) + \varepsilon_{N,t}, \tag{1.18}$$

in which $\Theta_N = \frac{\epsilon_N}{\epsilon_N - 1}$ is the price markup and $\varepsilon_{N,t}$ is the cost-push shock.

Tradable sector. Perfect competition is assumed in the tradable sector. Firms in the tradable sector combine an imported intermediate good ($X_{M,t}$) and domestic value added goods ($V_{H,t}$) with the following CES production function:

$$Y_{H,t} = \left[(\gamma_v)^{\frac{1}{\rho_V}} (V_{H,t})^{\frac{\rho_V - 1}{\rho_V}} + (1-\gamma_v)^{\frac{1}{\rho_V}} (X_{M,t})^{\frac{\rho_V - 1}{\rho_V}} \right]^{\frac{\rho_V}{\rho_V - 1}}, \tag{1.19}$$

in which $0 \le \gamma_v \le 1$ is the share of domestic tradable goods in tradable output, and $\rho_V > 0$ is the elasticity of substitution between imported intermediate goods and domestic value added goods. Domestic value added goods are produced with labor and tradable capital:

$$V_{H,t} = \left[A_t^H L_t^H \right]^{1-\alpha_h} \left[K_{t-1}^H \right]^{\alpha_h}, \tag{1.20}$$

in which A_t^H is a labor-augmenting technology process in the tradable sector.

Productivity. Labor-augmenting technology processes are given by:

$$\frac{A_t^J}{A_{t-1}^J} = e^{\mu_{J,t}} \tag{1.21}$$

$$\mu_{J,t} = (1-\rho_{aJ}) \log A + \rho_{aJ} \mu_{J,t-1} + \varepsilon_{aJ,t}, \; J = N, H \tag{1.22}$$

in which $\varepsilon_{aJ,t} \sim N(0, \sigma_{aJ}^2)$, $0 \le \rho_{aJ} < 1$, $\mu_{J,t}$ is the growth rate of technology, which follows an AR(1) process, and $A > 0$ is the steady state growth rate of technology. This specification is convenient since it allows for the simulation of permanent productivity increases, e.g. a productivity shock at time t propagates in the level of productivity in future periods. The need to include such nonstationary technology process into the model is justified by the fact that productivity differential between the Czech Republic and the Euro Area is permanent and increasing over time. Note that this kind of productivity specification with permanent growth introduces nonstationarity into the model, and in order to compute the steady state of the model it is necessary to stationarize growing variables.

1.3.3 Wage Contracts

The 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, and thus in 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 in both sectors according to their demand. At the end, the employment agency collects the wage income, and pools it equally among all households. Therefore, the wage is common for all households.

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:

$$\max_{W_t^*(i)} E_t \sum_{s=0}^{\infty} (\beta\xi_W)^{t+s} \left\{ \lambda_{t+s}^c(i) W_t^*(i) \frac{W_{t+s-1}}{W_{t-1}} L_{t+s}(i) - l \frac{(L_{t+s}(i))^{1+\eta_L}}{1+\eta_L} \right\}, \tag{1.23}$$

subject to the labor demand condition:

$$L_t(i) = \left[\frac{W_t(i)}{W_t}\right]^{-\epsilon_W} L_t, \tag{1.24}$$

in which $W_t = (\int_0^1 [W_t(i)]^{1-\epsilon_W} di)^{\frac{1}{1-\epsilon_W}}$ is the aggregate wage index, and $\lambda_{t+s}^c(i)$ is the shadow price of consumption for labor type i. The first order condition gives the following expression:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_W)^{t+s} \frac{L_{t+s}(i)^{1+\eta_L}}{W_t^*(i)} \left[\frac{W_t^*(i)}{MRS_{t+s}(i)} \frac{W_{t+s-1}}{W_{t-1}} - \Theta_W \right] = 0, \tag{1.25}$$

in which $\Theta_W = \frac{\epsilon_W}{\epsilon_W - 1}$ is the wage markup, and $MRS_t(i)$ is the marginal rate of substitution between labor and consumption for labor type i. Log-linearizing this condition, and using the definition for the aggregate wage index W_t above, one can obtain the following wage Phillips curve:

$$\log \frac{\Pi_{W,t}}{\Pi_{W,t-1}} = \beta \log \frac{\Pi_{W,t+1}}{\Pi_{W,t}} + \frac{(1-\xi_W)(1-\beta\xi_W)}{\xi_W} \log (rmcw_t \Theta_W) + \varepsilon_{W,t}, \tag{1.26}$$

in which $rmcw_t$ is the real marginal cost for wages and $\varepsilon_{W,t}$ is the wage cost-push shock. Wage inflation rises with the real marginal cost for wages and expected higher wage inflation in the next period.

1.3.4 Foreign Sector

The price of exported goods and imported goods, expressed in the domestic currency, is equal to the tradable price. Thus, in this model the terms of trade are unitary by assumption. The so-called internal real exchange rate is given by:

$$Q_t^c = \frac{P_{H,t}}{P_{N,t}} \tag{1.27}$$

The CPI-based real exchange rate is calculated as:

$$RER_t = \frac{ER_t}{P_t} \tag{1.28}$$

Furthermore, as in Schmitt-Grohe and Uribe (2001), households can borrow from abroad at the nominal interest rate given by the exogenous world interest rate R_t^w multiplied by a risk premium, which increases in the real value of foreign debt, expressed in the domestic currency:

$$R_t^* = R_t^w \exp\left(-\phi_b \frac{B_t^*}{P_{H,t}}\right) \tag{1.29}$$

in which $\phi_b > 0$ is the feedback parameter to foreign debt. This condition ensures the stationarity of the small open economy model.

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

$$R_t = \frac{E_t\left(ER_{t+1}\right)}{ER_t} R_t^* * ers_t * \exp(ns_t^{ers}) \tag{1.30}$$

in which ers_t is a UIP shock with persistence $\rho_e \in [0,1)$, and η_t^{ers} is a UIP news shock, defined in the following manner:

$$\begin{aligned} ns_t^{ers} &= ns_{1,t-1}^{ers} \\ ns_{1,t}^{ers} &= ns_{2,t-1}^{ers} \\ &\dots \\ ns_{T-1,t}^{ers} &= ns_{T,t-1}^{ers} \\ ns_{T,t}^{ers} &= \eta_t^{ers}, \end{aligned} \tag{1.31}$$

in which η_t^{ers} is a normally distributed shock, and T denotes the length of announcement period. The role of these news shocks is to make the simulations of the transition from a flexible to a fixed exchange rate regime more realistic, because the government can announce the fixed conversion exchange rate several periods before the actual implementation of a fixed exchange rate regime. Such a preannouncement alters the transmission mechanism of the economy with respect to the change in the exchange rate regime. In this light it is sensible to implement such an extension into the model.

The trade balance (net exports) equals the value of exports minus the value of imports:

$$NX_t = P_{H,t}\left[X_t - \left(C_{F,t} + X_{M,t} + I^H_{F,t} + I^N_{F,t}\right)\right], \tag{1.32}$$

in which X_t are exports. In equilibrium, trade is balanced.[9] The net foreign debt law of motion is given by the following relationship:

$$B^*_t = \frac{ER_t}{ER_{t-1}} B^*_{t-1} R^*_{t-1} + NX_t \tag{1.33}$$

Modeling a small open economy, foreign variables – specifically foreign inflation, and the foreign gross nominal interest rate – are exogenously given:

$$\begin{aligned} \frac{\Pi^*_t}{\Pi} &= \left(\frac{\Pi^*_{t-1}}{\Pi}\right)^{\rho_{pi*}} \exp(\varepsilon^{pi*}_t) \\ \frac{R^w_t}{R} &= \left(\frac{R^w_{t-1}}{R}\right)^{\rho_{rw}} \exp(\varepsilon^{rw}_t) \end{aligned} \tag{1.34}$$

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

1.3.5 Monetary Policy

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

$$R_t = (R_{t-1})^{\chi} \left[R \left(\frac{\Pi_t}{\Pi}\right)^{\phi_p}\right]^{1-\chi} \exp\left(mps_t + ns^{mps}_t\right) \tag{1.35}$$

in which R is the steady state nominal gross interest rate, $\phi_p \geq 0$ is the feedback coefficient to CPI inflation, Π is the central bank's inflation target, Π_t is the CPI inflation rate,

[9]This is an abstraction because the trade and current account imbalance could be large during the productivity catch-up with advanced economies. Nonetheless, impulse responses show that the B-S effect in this model is accompanied by large capital inflows under both exchange rate regimes (see Figure 1.8).

$0 \leq \chi < 1$ is the interest rate smoothing parameter, mps_t is exogenous monetary policy shock, and ns_t^{mps} is monetary policy news shock, defined similarly to the UIP news shock in the array of equations (1.31). The monetary policy news shock is, similarly to the UIP news shock, introduced because of possible preannouncement of the change from flexible exchange rate regime to the fixed one.

1.3.6 Market Clearing and Aggregation

Nontradable and tradable sector resource constraints are as follows:

$$Y_{N,t} = C_{N,t} + I_{N,t}^{N} + I_{N,t}^{H} \tag{1.36}$$

$$Y_{H,t} = C_{H,t} + I_{H,t}^{N} + I_{H,t}^{H} + X_t \tag{1.37}$$

Aggregate output equals the value of nontradable and tradable output deflated by the CPI price:

$$Y_t = \frac{P_{N,t}}{P_t} Y_{N,t} + \frac{P_{H,t}}{P_t} Y_{H,t} \tag{1.38}$$

1.3.7 Calibration

The parameters of the model were either calibrated or estimated. In this section the parameters which were calibrated are described. For comparison purposes, our calibration follows mainly Ravenna and Natalucci (2008). A complete list of calibrated parameters can be found in Table 2.1 in the Appendix.

The discount factor is set to conventional value $\beta = 0.99$, which corresponds to a steady state real interest rate of 4%. The parameter of disutility of providing labor supply l is set roughly so that steady state labor supply $L^s = \frac{1}{3}$. The share of nontradables in consumption and investment baskets $\gamma_n = 0.6$, and the share of domestic tradable goods in the tradable consumption and investment good is $\gamma_h = 0.8$. The elasticity of substitution between nontradable varieties equals $\epsilon_N = 11$. The production in the tradable sector is more capital-intensive compared to the nontradable sector, specifically $\alpha_h = \frac{2}{3}$ and $\alpha_n = \frac{1}{3}$. The share of domestic value added in tradable production is $\gamma_v = 0.5$. The capital depreciates at a quarterly rate of $\delta = 0.025$. The steady state growth rate of technology A is set so that the yearly growth rate of technology equals 4%.

1.3.8 Data and Estimation

The model is estimated on a total of 14 variables for the period from 1998 to 2013 at quarterly frequency. Specifically, the data set covers the GDP expenditure components (consumption, investment, imports), including both real variables and their respective deflators, domestic variables (nominal wages, 3-month PRIBOR rate, nominal exchange rate CZK/EUR), and foreign variables (3-month EURIBOR rate, PPI for EMU). The majority of data were collected from the Czech Statistical Office, while domestic financial variables come from the Czech National Bank, and foreign variables come from EUROSTAT.

Having a two-sector model, it is also desirable to utilize some sector specific data in the estimation. Therefore, tradable and nontradable components of consumption, investment and CPI inflation were extracted. Tradable consumption includes durable, semi-durable, and non-durable goods, whereas services are included in nontradable consumption. Tradable investment covers cultivated assets, transport equipment, and other machinery and equipment. Nontradable investment comprises dwellings, other buildings and structures, and intangible fixed assets. Nontradable inflation covers services, whereas tradable inflation follows price changes in food, fuel and other tradable goods.

In the estimation, a stationary version of the model is used, e.g. productivity growth is temporary, and the inflation target is set to zero.[10] Input data are detrended with an HP-filter, which means that only the business cycle information is retained. Observed data are linked to the model variables through a block of measurement equations. In these equations, the model variables are the sum of observed data and the measurement error. The standard deviation of 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 were chosen as follows. For parameters constrained on the interval $\langle 0, 1 \rangle$, the beta distribution is used. This concerns, for example, the elasticity of substitution between nontradable and tradable goods in the CES aggregates ρ_N, which reflects the idea that nontradable and tradable goods are likely to be complements. The standard errors of shocks have priors from inverse gamma distributions. In addition, the feedback parameter to foreign debt ϕ_b has a prior from

[10] First, growing variables are detrended by the technology process in the nontradable sector – for more elaboration how exactly this detrending is done see the following Section 1.3.9. Second, there is no need to rewrite the F.O.C. equations of the model, just the inflation target and annual technology growth are set to zero (i.e. $\Pi = 1$, $\mu_{T,t} = \mu_{N,t} = 1$). Third, the technology processes are expressed in a stationary form: $log(A_t^J) = \rho_{aJ} log(A_{t-1}^J) + \varepsilon_{aJ,t}$, $J = N, H$.

inverse gamma distribution, since it attains rather low values. For remaining parameters, the priors take the form of a normal distribution.

Estimation itself is carried out in the Dynare Toolbox.[11] The prior distributions of a subset of the model parameters are combined with the likelihood function based on the observed data. This results in posterior distributions for particular parameters. First, the Dynare is instructed to use numerical optimization techniques to search for the posterior modes of the parameters. Next, the draws from the posterior distributions around these modes are taken using the random walk Metropolis-Hastings (MH) algorithm. To ensure that convergence of the posterior simulations has been achieved, three parallel MH blocks are run, with a length of 200,000 draws. The first half of the draws become thrown away as a burn-in. Both simulations result in average acceptance rates of approximately 26%. Figures 1.5 through 1.7 in the Appendix show the comparison of the prior/posterior distributions and the results of the multivariate convergence diagnostic test. During the estimation, two parameters – persistences of nontradable technology and world nominal interest rate – indicated the presence of computational problems. Thus, they were removed from the estimation and their values were calibrated.

A comparison of the prior and posterior distributions for the estimated parameters can be found in Table 2.3 in the Appendix. A high posterior mean of the inverse elasticity of labor supply $\eta_L = 4.4$ suggests low elasticity of labor supply in the Czech Republic. The estimated value of habit parameter $\chi_c = 0.6$ implies that the households care about smoothing their consumption over time. Observed data favored the posterior mean for the elasticity of substitution between nontradable and tradable goods in the CES aggregates $\rho_N = 0.76$; however, there was little information in the data for the elasticities of substitution between domestic and foreign goods (ρ_H, ρ_V), for which prior and posterior means are roughly the same. Calvo probabilities in the nontradable sector and wage setting (ξ_N, ξ_L) turned out to be rather low, showing that nontradable firms adjust their prices on average every two quarters $(\sim 1/(1-0.4))$ and that wage contracts are rather flexible, renewed on average every quarter. The interest rate smoothing parameter $\chi = 0.4$ achieves a slightly lower value than its prior mean. The feedback coefficient to the inflation gap is rather strong, with posterior mean $\phi_p = 2.7$. The feedback parameter to foreign debt achieves $\phi_b = 0.002$, which is lower than its prior mean. Posterior means for persistences in autoregressive processes attain values between 0.4 to 0.8, with the smallest one associated with the UIP shock and the largest one with the demand

[11] Matlab-based toolbox, for further information see www.dynare.org.

shock. The estimates of the standard deviations of structural shocks point to the fact that productivity shock in the tradable sector is the most volatile.

1.3.9 Steady State

Given the calibrated and estimated parameters of the model, the steady state of the model is computed. Estimated parameters are evaluated at their posterior means. Since the model involves several price levels, one price level is taken as a numeraire and the remaining prices are expressed with respect to this chosen numeraire. Further, as was pointed out earlier, the presence of permanent productivity shocks makes the model nonstationary, and consequently it is not possible to directly compute its steady state. Therefore, one needs to perform additional transformations – a detrending of growing variables – in order to solve for the steady state. The detrending of the variables is as follows. Except for the labor supply, real variables are divided by the level of the labor-augmenting technology process in the nontradable sector, e.g. $\tilde{X}_t = X_t/A_t^N$, where $\tilde{X}_t$ is the transformed or detrended variable. The selection of technology process for detrending is arbitrary, but in the simulations of the B-S effect the productivity growth in the tradable sector is faster than in the nontradable sector, and to judge directly the effects of excessive growth in the tradable sector on real variables, it is preferable to express real variables with respect to the technology process in the nontradable sector. Another issue here is that the detrending of the shadow price of consumption λ_t^c (or the Lagrange multiplier associated with the budget constraint) is somewhat more complicated because a transformed version of this variable is given by the original one multiplied both by the numeraire price level and by the technology process in the nontradable sector. Subsequently, all optimality conditions are rewritten in detrended variables. 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.[12]

[12] IRIS is a MATLAB toolbox for macroeconomic modeling and forecasting, developed by Beneš (2014). For further information see www.iris-toolbox.com.

1.4 The Results

In this section several simulations are carried out. Firstly, impulse responses to productivity shock in the tradable sector are inspected, both under flexible- and fixed-exchange-rate regimes. Secondly, the transition from a flexible to fixed exchange rate is modeled in the context of the B-S effect. Thirdly, the fulfillment of selected Maastricht Criteria is assessed through the identification of structural shocks that drive the movements in the CPI inflation rate and nominal exchange rate. Forthly, the issue raised by Masten (2008) about the appropriate simulation of the B-S effect is briefly addressed. Lastly, the robustness of the results is checked.

1.4.1 The B-S Effect under Flexible and Fixed Exchange Rate Regime

For the purposes of comparison, the B-S effect is simulated as in Ravenna and Natalucci (2008), assuming a 30% gradual productivity increase in the tradable sector over 10 years. This growth is also relative to the foreign economy, and thus can be re-interpreted as excess relative productivity growth against the foreign economy (Euro Area). At the beginning of the simulation it is assumed that the economy is in its steady state. Although the initial calibrated shock in the productivity growth in the tradable sector is temporary (see equation 1.22), it gradually builds into a permanent 30% productivity increase in the tradable sector. Recalling the empirical evidence on productivity growth in Figure 1.2, this productivity increase mimics the observed productivity differential between the Czech Republic and the Euro Area. Impulse responses to calibrated productivity shock are depicted in Figure 1.8 in the Appendix. Blue lines represent the simulation with a fixed exchange rate, and red lines with a flexible exchange rate. In the simulation with a fixed exchange rate, the monetary policy rule is turned off, and the domestic interest rate equals the foreign interest rate, as defined in equation 1.29.

Except for the nominal exchange rate, it does not matter what kind of exchange rate regime is adopted in the economy, flexible or fixed, since the impulse responses overlap in the long run. Under the flexible-exchange-rate regime, the nominal exchange rate appreciates by about 6% in the long run, as productivity grows by 30% in the tradable sector. However, in the short run, the dynamics differ between these two exchange rate regimes. With a fixed-exchange-rate regime, there are stronger inflationary pressures, with CPI inflation rising on impact by approximately 7 percentage points in the annualized terms. This inflation arises solely from the nontradable sector because tradable inflation is linked to foreign tradable inflation, which is unaffected by the shock to domestic tradable productivity. Note that under a fixed exchange rate, the inflationary pressures cannot be mitigated with the monetary policy by definition. With a flexible exchange rate, inflation drops on impact, which is given by an initial appreciation of the nominal exchange rate. There are still some inflationary pressures coming from the nontradable sector, although notably smaller compared to the fixed-exchange-rate regime. The CPI-based real exchange rate appreciates approximately 6% in the long run under both exchange rate regimes.

Comparing the two exchange rate regimes, there is an obvious trade-off between nominal exchange rate appreciation and inflationary pressures in response to the productivity shock in the tradable sector. Either there are higher inflationary pressures with a fixed-exchange-rate regime, or higher nominal exchange rate appreciation in the case of a flexible-exchange-rate regime.

Qualitatively, these results resemble those of Ravenna and Natalucci (2008), but the extent of exchange rate appreciation in this paper is found to be somewhat smaller. Some difference might be attributable to the different calibration and structure of their model (for details see Table 1.3 in the Appendix). Overall, the model mimics the theoretical predictions of the B-S effect well, captured by appreciating exchange rates and/or rising inflationary pressures in response to growing productivity in the tradable sector.

1.4.2 Transition from Flexible to Fixed Exchange Rate

Currently, the Czech economy has a floating exchange rate, which will switch to a fixed exchange rate after the adoption of the Euro. Therefore, it is interesting to inspect what is likely to happen to the economy before, during, and after the adoption of the Euro on the back of the productivity catch-up process to the rest of Europe.

Performing such a simulation is not straightforward, since after the switch, a different set of equations describe the economy. Specifically, monetary policy loses its power to control the domestic interest rate, and the domestic interest rate equals the foreign interest rate (including a risk premium). To allow for such a change in the model, one possible approach is to adjust affected equations with desired calibrated shocks. Firstly, the UIP shocks (in Eq. 1.30) are calibrated so that the nominal exchange rate remains fixed after the switch.[13] Secondly, to achieve a fixed exchange regime, monetary policy shocks to the monetary policy rule (in Eq. 2.61) are calibrated so as to make the domestic interest rate equal to the foreign interest rate.[14] The calibration of monetary policy shocks is somewhat challenging since the domestic interest rate is an endogenous variable, whose trajectory is unknown prior to the simulation. Hence, initially, the trajectory of the domestic interest rate is conditionally set after the switch to its steady state level. A preliminary simulation is run, and the difference between the trajectories of domestic and foreign interest rates is computed. In the next iteration, the trajectory of the domestic interest rate is set according to the last known trajectory of the foreign interest rate. The iterations continue until the difference between the trajectories of the domestic and foreign interest rates are minimized. In this way, one searches for desired monetary policy shocks that would deliver a state in which the domestic interest rate equals the foreign interest rate, i.e. the condition valid in a fixed exchange rate regime.

Again, as in the previous section, a 30% gradual productivity increase in the tradable sector over 10 years is assumed, but at some point the transition from a flexible to a fixed exchange rate occurs. What is relevant for the dynamics in the transition is the level of nominal exchange rate which will be valid after the adoption of the Euro, i.e. what the conversion rate is that will fix the Czech crown against the Euro. Basically, the country might fix its exchange rate at a depreciated, appreciated, or consistent level as compared to the previous level of nominal exchange rate in the floating regime. Furthermore, the story is different when transition to a fixed exchange rate regime occurs during episodes of higher or lower productivity gains. What also matters for the transition is whether the conversion rate is preannounced to the public or not. All these issues are addressed in the following text.

In Figure 1.9 in the Appendix, the trajectories of selected variables are shown for the transition from a flexible to a fixed exchange rate. The switch occurs in the 8th quarter, and the level of fixed exchange rate is preannounced 4 quarters ahead of the switch, which is highlighted by a shaded area. It means that in period 4 all agents in the economy receive the news that in period 8 fixed exchange rate regime will be introduced, fixed at the specific exchange rate announced at period 4. Gold trajectories are for the

[13] More specifically, at the announcement period there is a calibrated news shock η_t^{ers}, which is simulated as anticipated. In addition, exchange rate shocks ers_t, following the time of switch, are simulated in an unanticipated manner.

[14] Monetary policy news shocks ns_t^{mps} are calibrated from the announcement period and further (until the end of simulation horizon minus the length of the announcement period), and are simulated as anticipated.

case of a flexible exchange rate, that is, without the switch to a fixed exchange rate. Red trajectories are for the case in which the fixed exchange rate is set to the last value of the flexible exchange rate. Black/blue trajectories are for depreciated/appreciated fixed exchange rates by 1 percentage point compared to the case in which the exchange rate would remain flexible at the time of the switch. Comparing the results, the highest inflation pressures occur in the case of a depreciated fixed exchange rate, as a large proportion of inflation is imported from abroad through a depreciated currency. Across different conversion rates, the dynamics of real variables, such as output or consumption, remain largely intact, especially in the long run. Soon after the switch to a fixed exchange rate regime, CPI inflation reaches similar trajectories for all cases. In the "red" case, which represents the fix at the last value of the flexible exchange rate, CPI inflation in the first year after the switch is, on average, approximately 0.4 percentage points higher compared to the case of the flexible exchange rate.

The timing of the transition from a flexible to a fixed exchange rate regime is also of key importance. The comparison of two different timings of transition is shown in Figure 1.10 in the Appendix. Red lines depict the simulation in which a fixed exchange rate is adopted in period 8, when the average productivity growth of a tradable sector is approximately 4% annually. Blue lines represent the case in which a fixed exchange rate is adopted in period 20, with slower productivity growth in the tradable sector reaching around 1% annually. Comparing these two simulations, early adoption of the Euro brings additional inflation costs, amounting to, on average, 0.3 percentage point higher CPI inflation when compared to the alternative case of a later transition. However, the timing of the transition does not matter for the inflationary pressures prior to the adoption of the Euro. Further, the dynamics of real variables are almost unaffected by a different timing of the transition. The results suggest that a country should consider at what stage of the productivity catch-up process it should enter the EA, since early transition may be associated initially with higher inflation, rising by some 0.4 percentage points in the first year after the adoption of the Euro. These higher inflation pressures do not seem large, but one should bear in mind that they cannot be mitigated by domestic monetary policy, since its power is lost in the fixed exchange rate regime.

To be more realistic, this timing exercise is also repeated using a labor productivity differential as a proxy for actual productivity improvement between the Czech Republic and the Euro Area, depicted in Figure 1.2 over the 2000–2015 time periods. Real labor productivity per hour worked is extracted from the Eurostat database (variable namq_10_lp_ulc), and seasonally adjusted by the Tramo/Seats method. To eliminate short-run fluctuations, the productivity differential is smoothed with the H-P filter, with the smoothing parameter set to 5. For comparison, this productivity differential is also plotted against the autoregressive process for the tradable/nontradable technology wedge used in previous simulations (grey line). Current data show that productivity improved in the Czech Republic relative to the Euro Area by more than 30% between 2000 and 2008, but since the Great Recession, the productivity catch-up process has stalled. Figure 1.11 shows the different timing of the transition from a flexible to a fixed exchange rate regime on the background of a current productivity differential. Early transition occurs in the 2nd quarter of 2004 (to reflect the entry of the Czech Republic into the European Union), whereas later transition is at the beginning of 2009 (chosen as the time when Slovakia entered the Euro Area). Comparing these two timings, hypothetical early adoption of the Euro brings additional inflationary costs, reaching, on average, 0.4 percentage point higher CPI inflation when compared to the later transition. Initially, inflation rises by 0.6 percentage points in the first year after early adoption of the Euro. In the event that the exchange rate remains flexible until the later transition, the nominal exchange rate appreciation driven by the B-S effect is stronger by approximately 2 percentage points compared to the case of early transition.

This was a backward looking simulation, so another important point is to understand whether the B-S effect can lead to violation of the Maastricht criteria in the future. For that purpose the next simulation is run on prolonged productivity improvement between the Czech Republic and the Euro Area. The productivity differential is extended after 2019 by the average productivity change, recorded over the 2017–2019 time horizon, with a slowly decreasing pace over time. This trajectory is displayed in the bottom right picture of Figure 1.12; note that prolongation starts at the beginning of shaded area (labeled as period 81). Similarly to the previous simulation, Figure 1.12 shows the different timing of the transition from a flexible to a fixed exchange rate regime, but this time on the background of the future productivity differential.[15] Early transition happens in the beginning of 2020, whereas the later is from 2023. Earlier adoption of the Euro in 2020 brings additional inflationary costs, amounting to around a 0.2 percentage points higher CPI inflation when compared to the later transition in 2023. With later adoption of the Euro in 2023 the nominal exchange rate appreciates further by 0.6 percentage points

[15] To make this figure more readable, the results are shown from simulation period 30. The lines from the beginning of the simulation until period 30 are identical to the blue lines in the previous Figure 1.11.

compared to the case of early transition in 2020. In the light of these quantifications, the B-S effect itself is unlikely to violate the Maastricht criteria in the future.

The country might choose to adopt the single currency by surprise. Such simulation is available in Figure 1.13 in the Appendix, with red/blue lines showing the unexpected/expected switch to a fixed exchange rate regime. Further, it is arbitrarily assumed that a depreciated fixed exchange rate by 1 percentage point is to be adopted, compared to the case in which the exchange rate would remain flexible at the time of the switch. Inspecting the results, the adoption of the Euro by surprise does not seem to be preferable, since it is associated with higher inflation at the time of the switch.

As regards optimal timing of the Euro adoption, the model developed does not itself provide sufficient guidance. Perhaps one may impose an additional constraint on the size of the costs of early adoption of the Euro, e.g. in terms of acceptable higher inflationary pressures (for instance 1 percentage point higher inflation over a specific horizon). Given the inflationary costs, the maximum size of the productivity growth differential could possibly be calculated, which would satisfy the additional constraint. Nonetheless, if zero inflationary costs are preferred by policy-makers, then optimal timing of the Euro adoption is to wait until the convergence process of the Czech Republic with the Euro Area is fully achieved.

1.4.3 Fulfillment of the Maastricht Criteria

The DSGE model I developed can be used to assess the fulfillment of selected Maastricht Criteria. This is done by inspecting what structural shocks of the model explain the movements in relevant macroeconomic variables, focusing on CPI inflation and the nominal exchange rate throughout the period from 1998 till 2019.

Decomposition of the annual rate of CPI inflation into the contributions of structural shocks is depicted in Figure 1.14 in the Appendix. The CPI inflation line in black represents the deviation of the annual growth rate from the central bank's inflation target. The inflation target changed a couple of times in the period studied. From 2002 till 2006 there was an inflation band, 2 percentage points wide, with its middle standing at 4% in the beginning of 2002 and gradually decreasing to 3% by the end of 2005. The point inflation target was set to 3% between 2006 and 2009, and from 2010 amounts to 2%. The grey line shows the Maastricht reference values for the inflation criterium, taken from the convergence reports of the European Commission, minus the CNB's inflation target. This line starts in 2006, when the first assessment of fulfillment of the Maastricht Criteria for the Czech Republic was made. To elaborate more on the Maastricht inflation criterion in this figure, take for instance the convergence report of the European Commission (2018), when the reference value for the inflation rate was 1.8%. This reference value is expressed as a deviation from the inflation target; thus the grey line is at -0.2% from 2018Q2 until the end of 2019 (the next convergence report was published in 2020). The shaded areas in this figure signal the periods when the inflation criterion was violated in the Czech Republic, i.e. the actual inflation rate was higher than the reference value listed in the convergence reports.

The contributions of productivity shocks are depicted with green colors. The role of productivity shocks is noticeable in explaining the movements of the inflation rate from the target; nevertheless, the biggest contributions seem to come from monetary policy shocks (in orange) and exchange rate shocks (in red). Productivity shocks tend to explain inflationary pressures, with the highest contribution identified at the end of 2009, reaching around 1 percentage point. In the four relevant shaded regions the productivity shocks are not the main driver behind the violation of the inflation criterion. More specifically, in 2006Q2-Q3 the highest contributions are found due to shocks to the foreign interest rate, and in 2007Q4 and 2018 the highest contributions to the inflation rate are identified by monetary policy and exchange rate shocks. Similarly, in the period from 2010Q2 till 2012Q3 upward inflationary pressures came mainly from exchange rate and monetary policy shocks, and only to some minor extent from productivity shocks. In the period from 2016Q4 until the end of 2019, the inflation criterion seem to be violated mainly due to structural shocks to the exchange rate, consumption preferences and monetary policy; inflation pressures arising from productivity shocks seem rather small in this last period.

The decomposition of the nominal exchange rate into the contributions of structural shocks can be found in Figure 1.15. The nominal exchange rate is expressed as the deviation of the annual change in the nominal exchange rate from the average yearly appreciating trend (which equals approximately 1.4% a year in the period analyzed) of the Czech Crown against the Euro. The Czech Crown is not participating in the ERM II mechanism yet, and thus officially the Czech Republic does not fulfil the exchange rate criterion. As opposed to the CPI inflation, the role of productivity shocks is larger in explaining the movements of the nominal exchange rate around its appreciating trend. Other important drivers are structural shocks to foreign variables: foreign inflation and interest rate. Excessive productivity growth, which occurred roughly from 2000 till 2007 and then from 2015 and on (recall the productivity growth differential in Figure 1.2), is able to explain, to some extent, the excessive appreciation of the nominal exchange rate.

1.4.4 Masten's Critique and Nonlinear Simulations

In this section, the issue of the proper simulation of the B-S effect raised by Masten (2008) is briefly addressed. Masten (2008) criticizes Ravenna and Natalucci (2008) for inappropriate simulation of the B-S effect, stating that: *"..real appreciation in response to their simulation of BS effect is not an equilibrium process. On the contrary, it is a consequence of a large deviation from the actual equilibrium productivity level of the economy leading to model dynamics that appear empirically unlikely."* Further in his paper he repeats his critique in other words: *"Natalucci and Ravenna (2002) construct the BS experiment by pushing a stationary process of tradable productivity very far away from equilibrium with a sequence of positive productivity shocks for 40 quarters. This means that at the time when tradable productivity is supposed to reach a new steady state value (in 10 years) is in fact the farthest away from the steady state. The tradable productivity increase is thus not constructed as an equilibrium-driving process."* As a remedy to this issue Masten (2008) proposes using permanent sector-specific shocks so as to properly simulate the B-S effect as an equilibrium-driving process.

Following the proposal of Masten (2008), my model allows the use of permanent sector-specific productivity shocks in the simulation of the B-S effect. Indeed, I attempted the simulation of the B-S effect with both permanent shocks and temporary shocks in the manner of Ravenna and Natalucci (2008), and obtained qualitatively the same results. For details see the impulse responses in Figure 1.16 in the Appendix for the case of flexible exchange rate regime, showing both the simulation with permanent productivity shocks (labeled as nonstationary and in black lines) and the simulation with temporary shocks (labeled stationary and in red lines), in which a stationary productivity process in the tradable sector is exogenized to match the desired productivity path.[16] Note that both simulations overlap, except for some minor unnoticeable numerical imprecision. In light of these results, Masten's critique of the paper by Ravenna and Natalucci (2008) seems to be unjustified.

[16]To make both simulations comparable, the steady state annual growth rate of technology is set to zero in the simulation with permanent productivity shocks; otherwise the steady states, from which the simulations start, would be different. Furthermore, the exogenous productivity path in the simulation with temporary shocks is fixed for a sufficiently long period (400 quarters).

So far, my model has been solved linearly. Nevertheless simulating productivity shocks may induce different behavior if the model is solved nonlinearly under perfect foresight. This is demonstrated in the same Figure 1.16, again depicting both kinds of simulations, with either permanent productivity shocks (in gold lines) or temporary long-lasting productivity shocks (in blue lines), but this time utilising a nonlinear solution. Both nonlinear simulations yield qualitatively the same results. The differences in nonlinear simulations with respect to the simulations run in a linear fashion do not significantly alter the transmission mechanism of the model. There are a few notable changes, for example those visible for the responses of the foreign interest rate or net foreign assets (reflecting among others the nonlinearities in equations 1.29 and 1.33), but these are not strong enough to change the main conclusions of this chapter. This also suggests that the approximation error of the model, which is solved linearly, is not an issue for simulating these kind of productivity shocks.

Concerning exchange rate appreciation driven by the B-S effect, in Masten (2008) it is only present when the model assumes an exogenous externality in the production costs. In my study such externality is not considered, and the simulation of the B-S effect results in exchange rate appreciation. Nonetheless, the conclusions of Masten (2008) and my study are similar in that the B-S effect is not an issue for the Czech Republic to fulfill the inflation and nominal exchange rate criteria.

1.4.5 Robustness

I checked the results against several alternative assumptions. Concerning the parameters of the model, perhaps the largest sensitivity of the results is found with respect to the elasticity of substitution between nontradable and tradable goods in the CES aggregates and the degree of price rigidity in the nontradable sector. Therefore, in this section these two parameters are varied to check the implications for the B-S effect.

Blue lines in Figures 1.17–1.18 in the Appendix show the simulations of the B-S effect assuming lower elasticity of substitution between nontradable and tradable goods $\rho_N = 0.5$, compared to the baseline in red lines with $\rho_N = 0.76$. Black lines in the same figures depict the simulations of the B-S effect assuming higher price rigidity in the nontradable sector $\xi_N = 0.8$, compared to the baseline where $\xi_N = 0.4$. Alternative calibrations of these two parameters are adopted from Ravenna and Natalucci (2008). Gold lines represent the combination of both lower elasticity of substitution between nontradable and tradable goods and higher price rigidity in the nontradable sector. Impulse responses in Figure 1.17 are in the case of a flexible exchange rate, and Figure 1.18 in the case of a fixed exchange rate.

Lower elasticity of substitution between nontradable and tradable goods makes the B-S effect under a flexible exchange rate regime more pronounced through nominal exchange rate appreciation. The nominal exchange rate appreciates by almost 8% over ten years; however, it does not breach the limit imposed by the ERM II mechanism. The effect on CPI inflation is similar to the baseline. There is a shift in the production patterns, with more production occurring in the nontradable sector in comparison to the baseline, which is given by different preferences over nontradable and tradable goods in the consumption/investment baskets. The B-S effect under a flexible exchange rate with a higher degree of price rigidity in the nontradable sector resembles the baseline; however, some differences are notable. The nominal exchange rate appreciates slightly more in the long run. Further, the response of nontradable inflation is initially below the baseline, but thereafter persistently higher in the long run.

The B-S effect under a fixed exchange rate regime with lower elasticity of substitution between nontradable and tradable goods is more amplified through CPI inflation, which reaches 13% on impact in annualized terms, compared to the 7% initial increase in the baseline. The impulse responses of real variables, such as output, consumption and real exchange rate, are similar to the case of a flexible exchange rate in the long run. The B-S effect under a fixed exchange rate regime with a higher degree of price rigidity in the nontradable sector becomes less pronounced through the response of CPI inflation. The initial response is roughly half compared to the baseline, but the response is longer-lived over the first two years.

Interestingly, the alternative calibrations do not significantly change the main conclusions of this paper concerning the additional inflation costs of early adoption of the Euro. The same simulations as in Figure 1.10 in the Appendix were replicated for alternative values of the elasticity of substitution between nontradable and tradable goods and the degree of price rigidity in the nontradable sector. In these simulations, early adoption of the Euro brings additional inflation costs, amounting to, on average, 0.2 percentage-point higher CPI inflation when compared to the alternative case of later transition. This is slightly less compared to the baseline, with, on average, 0.3 percentage-point higher CPI inflation over the period of early and later transition.

1.5 Conclusion

The B-S effect implies that highly productive countries have higher inflation and appreciating real exchange rates because of larger productivity growth differentials between tradable and nontradable sectors relative to advanced economies. This is also particularly important for the Czech Republic, in which a catch-up process with advanced European countries is still ongoing. At some point, the Czech Republic is obliged to adopt the Euro as a single currency. Before adopting the Euro, the Maastricht convergence criteria must be fulfilled, imposing, among others, limits on inflation and nominal exchange rate fluctuations. An ongoing convergence process or the presence of the B-S effect might restrain a country from complying with these Maastricht criteria. Therefore, the main goal of this study is to determine whether the B-S effect could be an issue for the Czech Republic in its ability to meet the Maastricht criteria.

For this purpose, I build a two-sector DSGE model of a small open economy, estimated for the Czech Republic using Bayesian techniques. The structure of the model is close to that in Ravenna and Natalucci (2008), but is extended by several more realistic features, including staggered wages, consumption habits, permanent productivity growth, and a non-zero inflation target. The prices are sticky in the nontradable sector, whereas in the tradable sector flexible prices are assumed and purchasing power parity holds for tradable goods.

The simulations from the model indicate that the B-S effect does not pose a problem for the Czech Republic in meeting the Maastricht convergence criteria before adopting the Euro. The costs of early adoption of the Euro are not large in terms of additional inflationary pressures which materialize after the adoption of the single currency. More specifically, early transition is associated with initially higher inflation, rising by some 0.4 percentage points in the first year after the adoption of the Euro. In addition, nominal exchange rate appreciation, driven by the B-S effect, does not breach the limit imposed by the ERM II mechanism. In the baseline version of the model, the nominal exchange rate appreciates by about 6% in the long run, as productivity increases by 30%.

My presented research can be extended in several ways. For example, the model can be improved by relaxing some of its underlying assumptions, such as a perfectly competitive tradable sector and balanced trade in the equilibrium. Further, one can extend its structure to include the fiscal block in order to study the implications of the B-S effect on the Maastricht fiscal criteria, which impose limits on government budget balance and debt. Another interesting extension would be to search for the optimal monetary policy, which would minimize the costs of the B-S effect before the adoption of the Euro.

Appendix

1.A Tables and Figures

Figure 1.2: Productivity Growth Differential

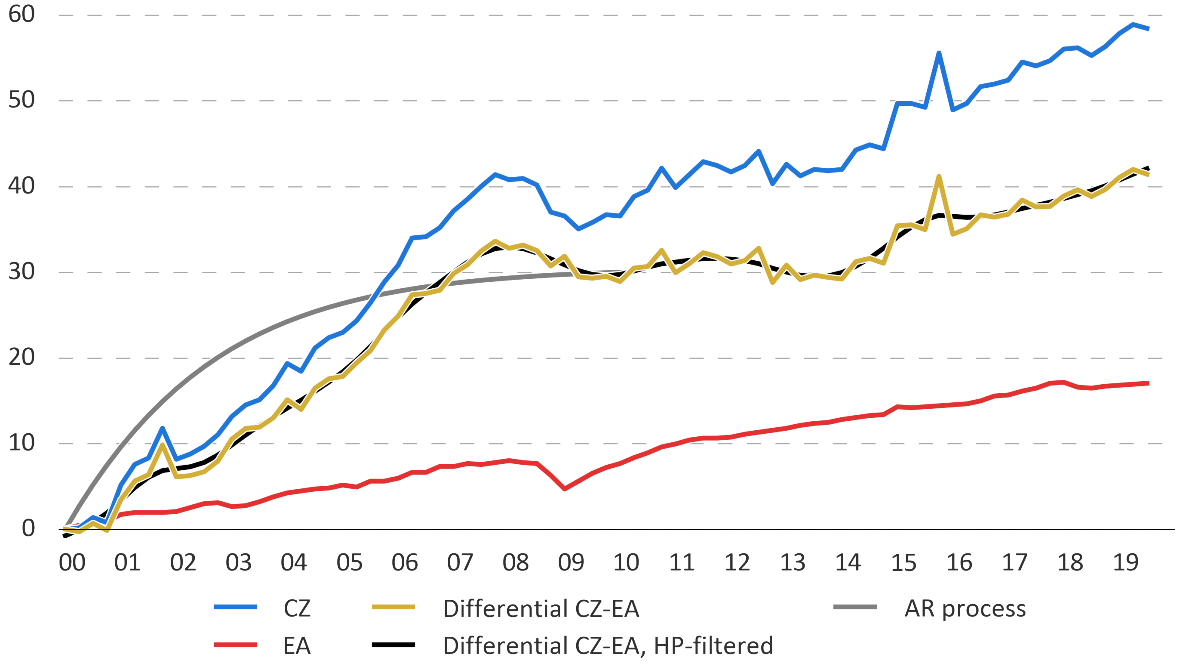


Figure 1.3: Inflation Differential

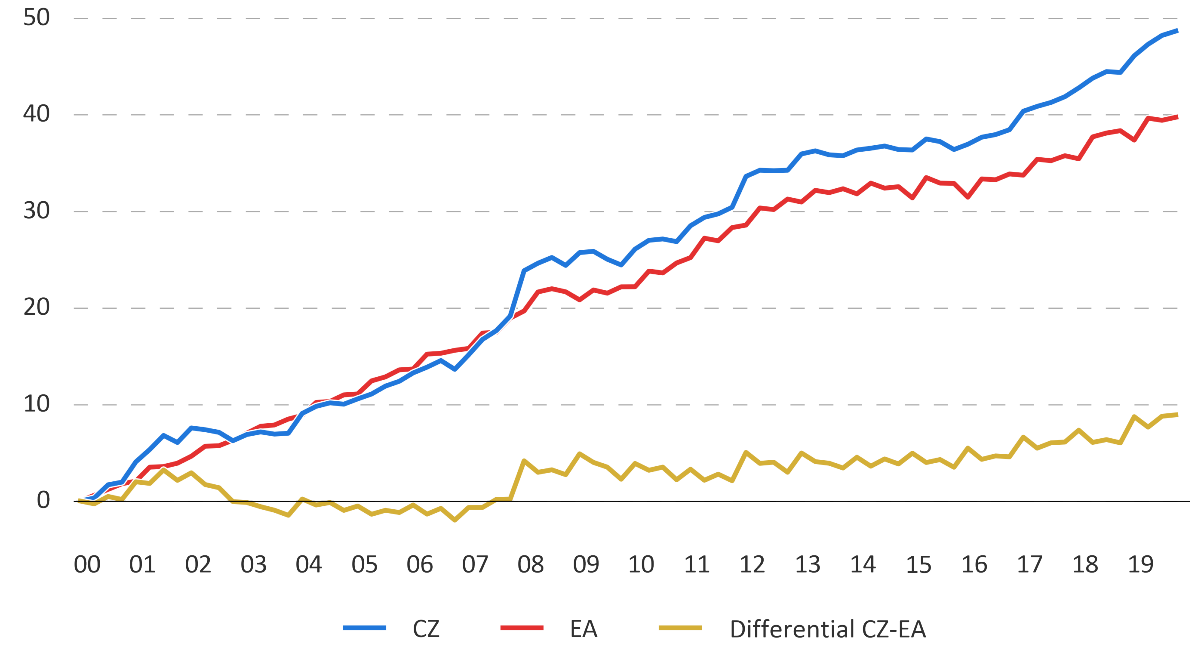


Figure 1.4: Real Exchange Rate

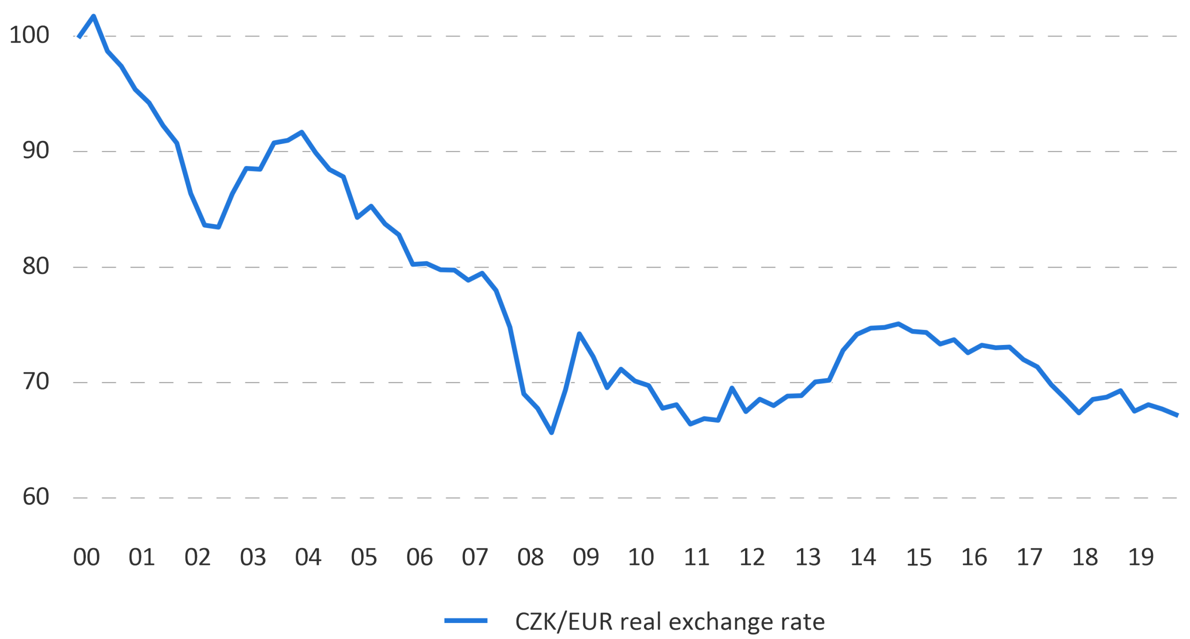


Table 1.1: Calibrated Parameters

Parameter	Description	Value
Preferences		
β	Discount factor	0.99
l	Disutility of labor supply	20
Technology		
A	Growth rate of technology	1.01
α_n	Capital share in nontradable sector	1/3
α_h	Capital share in tradable sector	2/3
δ	Depreciation rate	0.025
ϕ_0	Investment adjustment cost	0.5
Monetary policy		
$\overline{\Pi}$	Inflation target	1.05
Shares		
γ_n	Share of nontradables in CES aggregates	0.6
γ_h	Share of domestic tradable goods in CES aggregates	0.8
γ_v	Share of domestic value added in tradable production	0.5
Elasticity		
ϵ_W	Between labor varieties	11
ϵ_N	Between nontradable good varieties	11
Persistences		
ρ_{an}	Nontradable technology	0.95
ρ_{rw}	World nominal interest rate	0.95

Table 1.2: Estimated Parameters

Parameter (equation)	Parameter (figure)	Prior distribution	Posterior distribution mode	mean	10%	90%
Utility parameters						
η_L	etaL	N(2.5,0.2)	4.76	4.45	3.93	4.89
χ_c	chi_c	N(0.5,0.2)	0.51	0.55	0.43	0.68
Elasticities in CES aggregates						
ρ_N	rhoN	B(0.5,0.5)	0.75	0.76	0.67	0.84
ρ_H	rhoH	N(1.5,0.2)	1.47	1.51	1.26	1.76
ρ_V	rhoV	N(1.5,0.2)	1.47	1.50	1.25	1.76
Calvo probabilities						
ξ_N	xiN	B(0.5,0.5)	0.43	0.42	0.31	0.52
ξ_L	xiL	B(0.5,0.5)	0.19	0.17	0.11	0.23
Feedback coefficients						
ϕ_p	phi_p	N(2,0.2)	2.62	2.66	2.39	2.94
ϕ_b	phi_b	IG(0.01,0.1)	0.002	0.002	0.001	0.002
Persistences						
χ	chi	N(0.5,0.2)	0.43	0.43	0.34	0.52
ρ_{ah}	rho_ah	B(0.5,0.5)	0.71	0.69	0.61	0.77
ρ_{pi*}	rho_pi_star	B(0.5,0.5)	0.47	0.46	0.38	0.54
ρ_d	rho_d	B(0.5,0.5)	0.84	0.77	0.62	0.88
ρ_e	rho_e	B(0.5,0.5)	0.35	0.35	0.25	0.45
Standard errors of shocks						
$\varepsilon_{H,t}$	SE_eah	IG(0.01,0.1)	0.08	0.08	0.07	0.09
$\varepsilon_{N,t}$	SE_ean	IG(0.01,0.1)	0.02	0.03	0.02	0.03
ε_t^{rw}	SE_erworld	IG(0.01,0.1)	0.01	0.01	0.01	0.02
ε_t^N	SE_ecostpushPN	IG(0.01,0.1)	0.03	0.04	0.03	0.05
ε_t^{mps}	SE_emps	IG(0.01,0.1)	0.02	0.02	0.02	0.02
ε_t^W	SE_ecostpushW	IG(0.01,0.1)	0.05	0.06	0.04	0.09
ε_t^{pi*}	SE_epistar	IG(0.01,0.1)	0.02	0.02	0.01	0.02
ε_t^d	SE_ed	IG(0.01,0.1)	0.03	0.03	0.02	0.03
ε_t^s	SE_es	IG(0.01,0.1)	0.02	0.02	0.02	0.02

Table 1.3: Selected DSGE models with the B-S effect for the Czech Republic

Study	Model features	Parameters	Main results
Ravenna and Natalucci (2008)	• Price rigidity in nontradable sector • Perfect competition in tradable sector • Production with capital and labor • Capital accumulation with adjustment costs • Stationary productivity process • Taylor monetary rule	Calibrated	• In the presence of the B-S effect there is no monetary policy that would allow for meeting both the nominal exchange rate criterion and the inflation rate criterion. • The B-S effect raises the welfare loss of rules that prescribe a strong policy response to movements of the nominal exchange rate. • A productivity increase (30% over 10 years) induces approximately 2% nominal exchange rate appreciation per year.
Masten (2008)	• Price rigidities in tradable and nontradable sector • Cost externality • Permanent productivity growth • Production with labor • Optimal monetary policy	Calibrated	• The B-S effect is not a threat to meeting the Maastricht inflation criterion. • Optimal monetary policy, which targets both tradable and nontradable inflation, is able to stabilize inflation at levels of the rest of the world. • A productivity increase (30% over 10 years) induces on average 1.4% nominal exchange rate appreciation per year.
Ambrisko (2015)	• Price rigidity in nontradable sector • Perfect competition in tradable sector • Production with capital and labor • Capital accumulation with adjustment costs • Staggered wages • Consumption habits • Permanent productivity growth • Non-zero inflation target • Taylor monetary rule	Calibrated / Estimated	• The B-S effect is not an issue for the Czech Republic in meeting the inflation and nominal exchange rate criteria. • The costs of early adoption of the Euro are not large in terms of additional inflation pressures which materialize after the adoption of the single currency. • Early transition is associated with initially higher inflation, rising by some 0.4 percentage points in the first year after adoption of the Euro. • A productivity increase (30% over 10 years) induces on average 0.6% nominal exchange rate appreciation per year.

Figure 1.5: Bayesian Estimation: Priors and Posteriors of Estimated Parameters

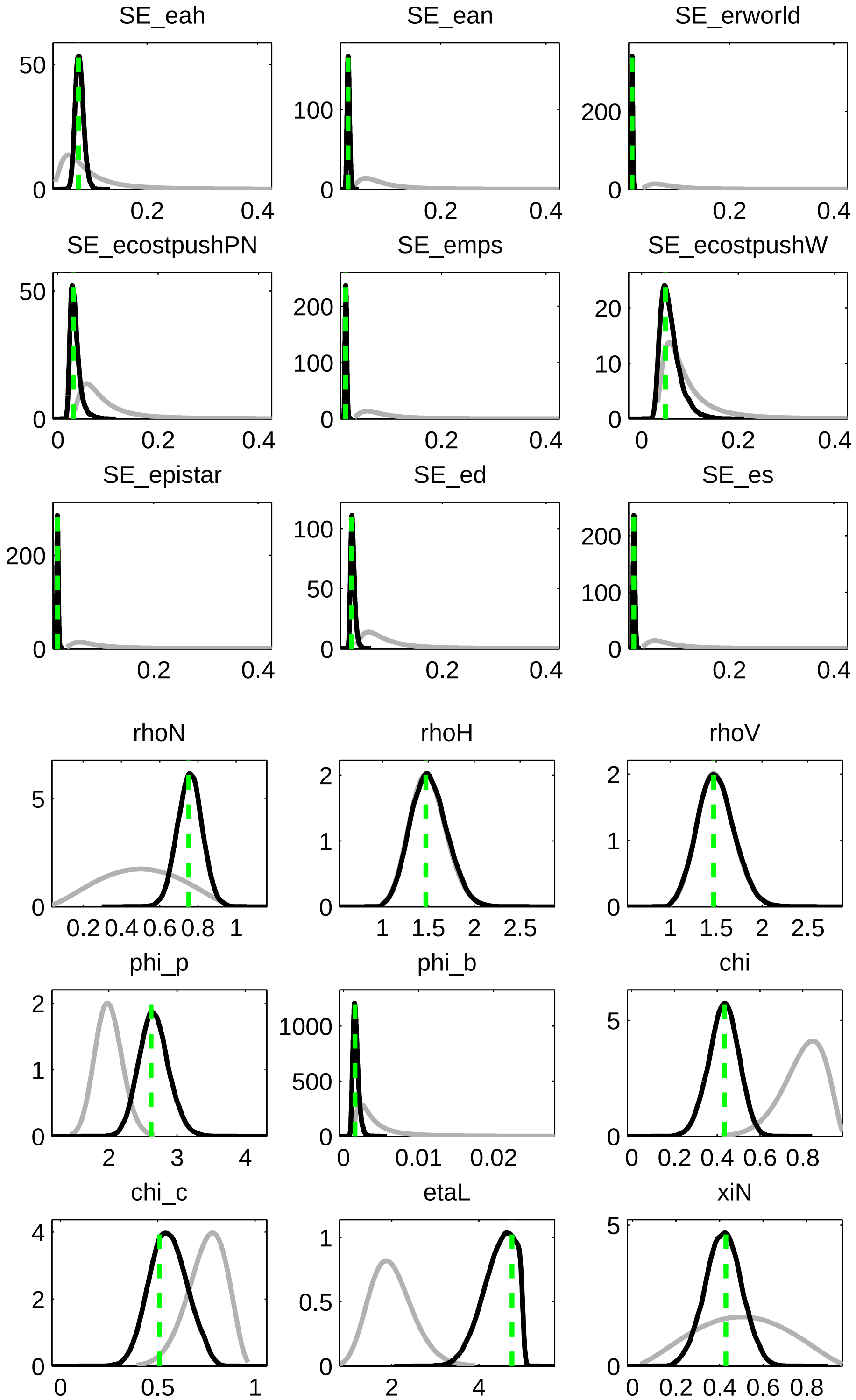


Figure 1.6: Bayesian Estimation: Priors and Posteriors of Estimated Parameters (Continued)

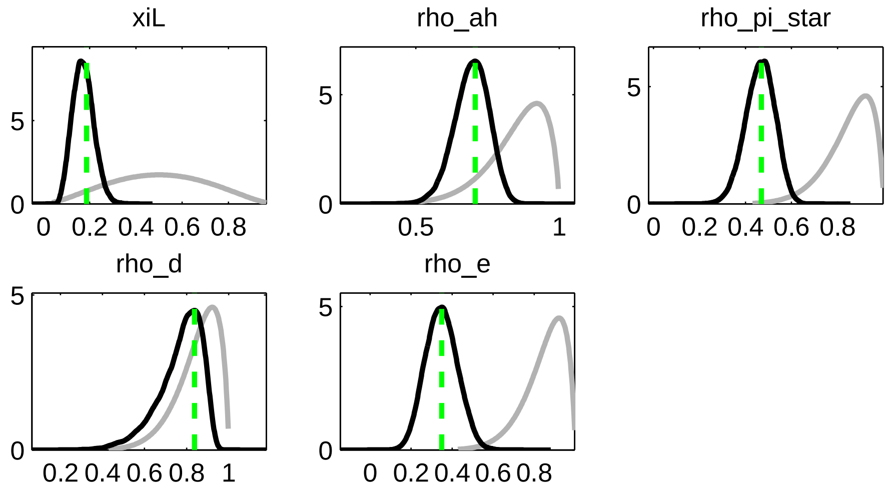


Figure 1.7: Bayesian Estimation: Multivariate Convergence Statistics

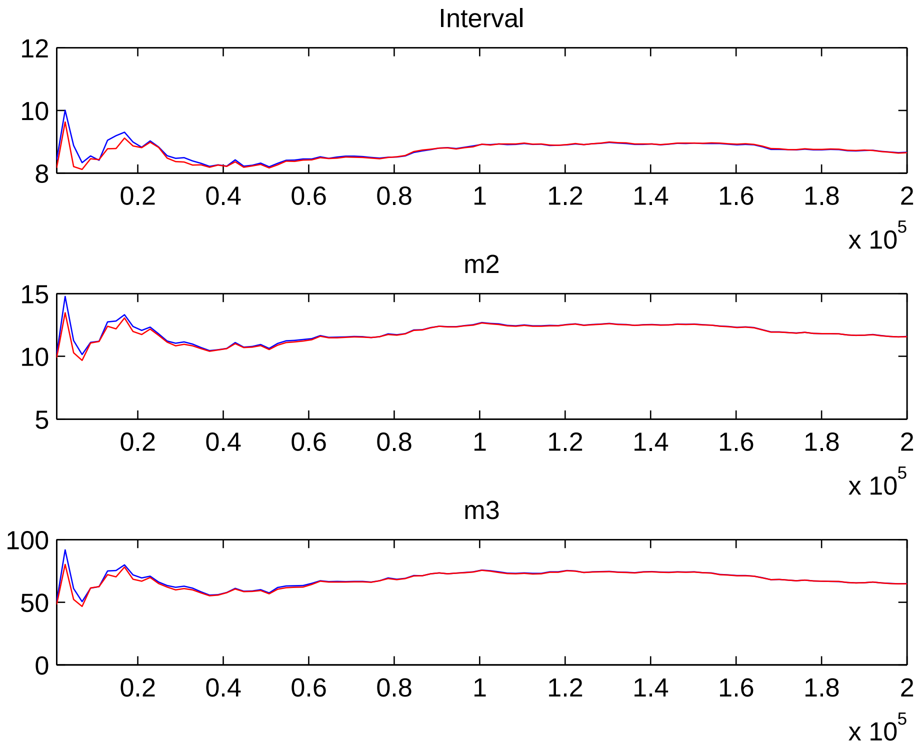


Figure 1.8: Tradable Productivity Growth by 30% over 10 Years

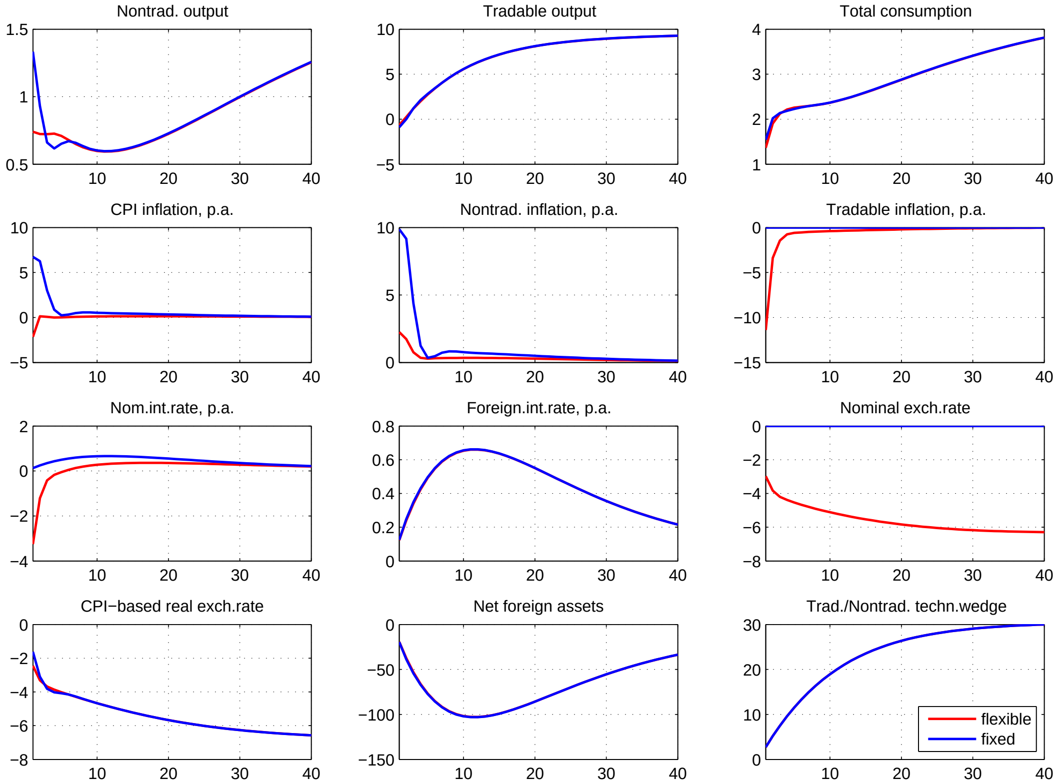


Figure 1.9: Transition from Flexible to Fixed Exchange Rate

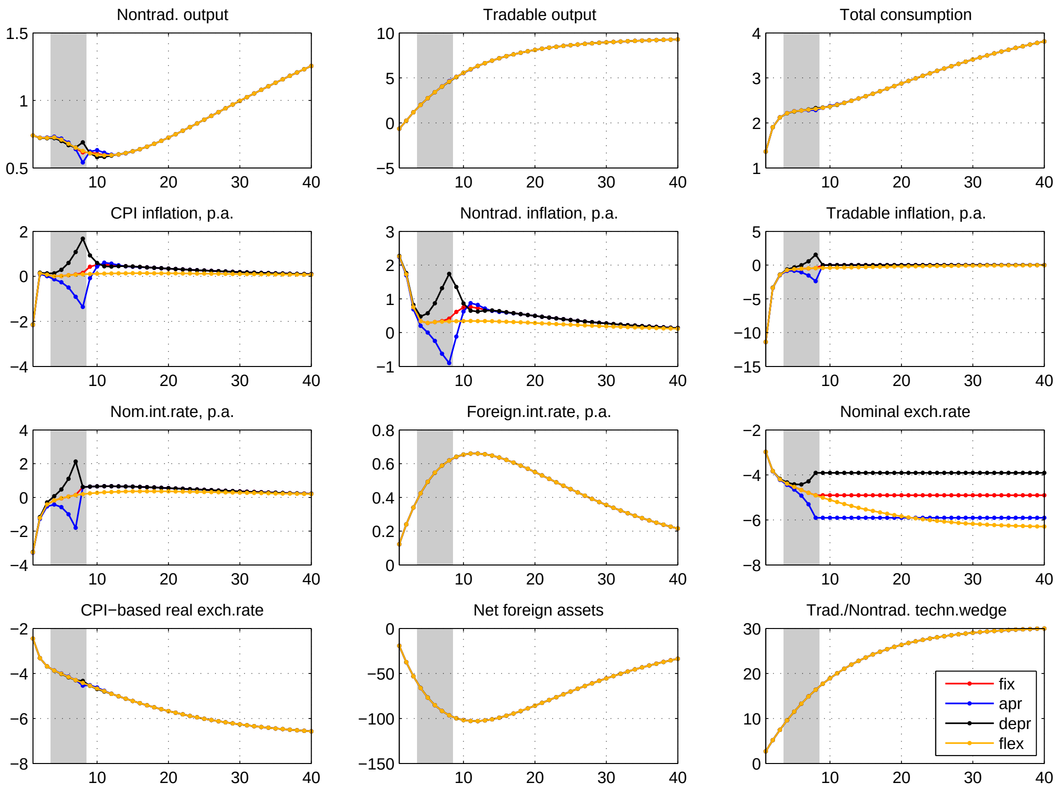


Figure 1.10: Different Timing of Transition

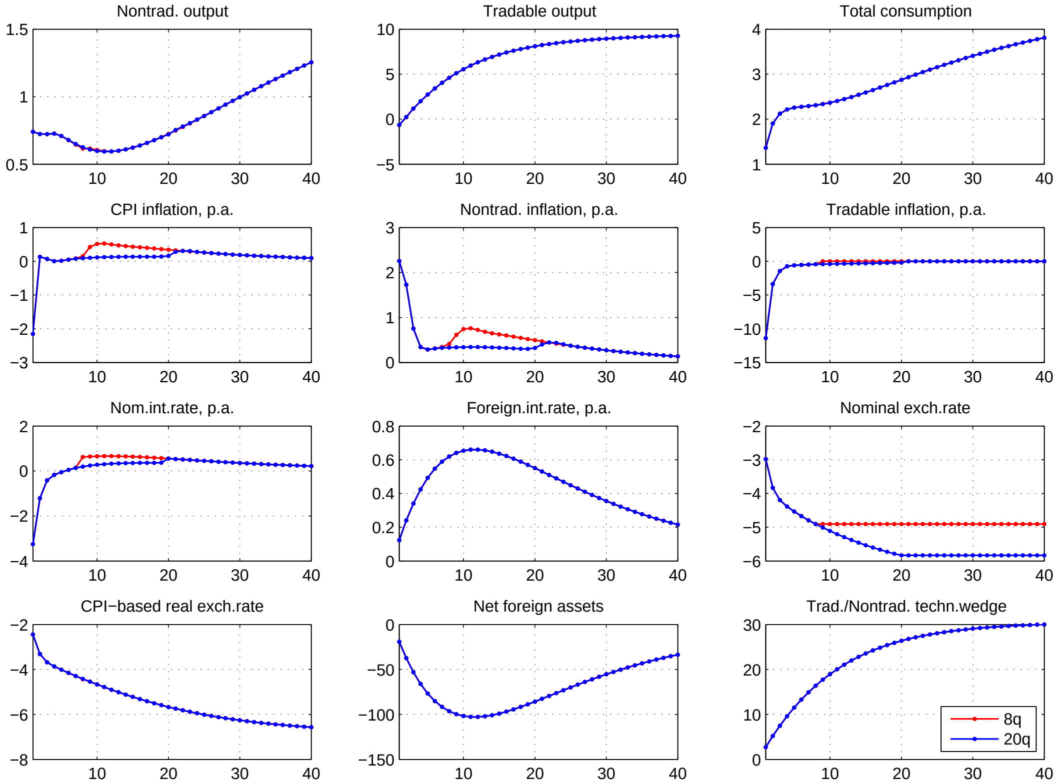


Figure 1.11: Different Timing of Transition with Actual Productivity Path

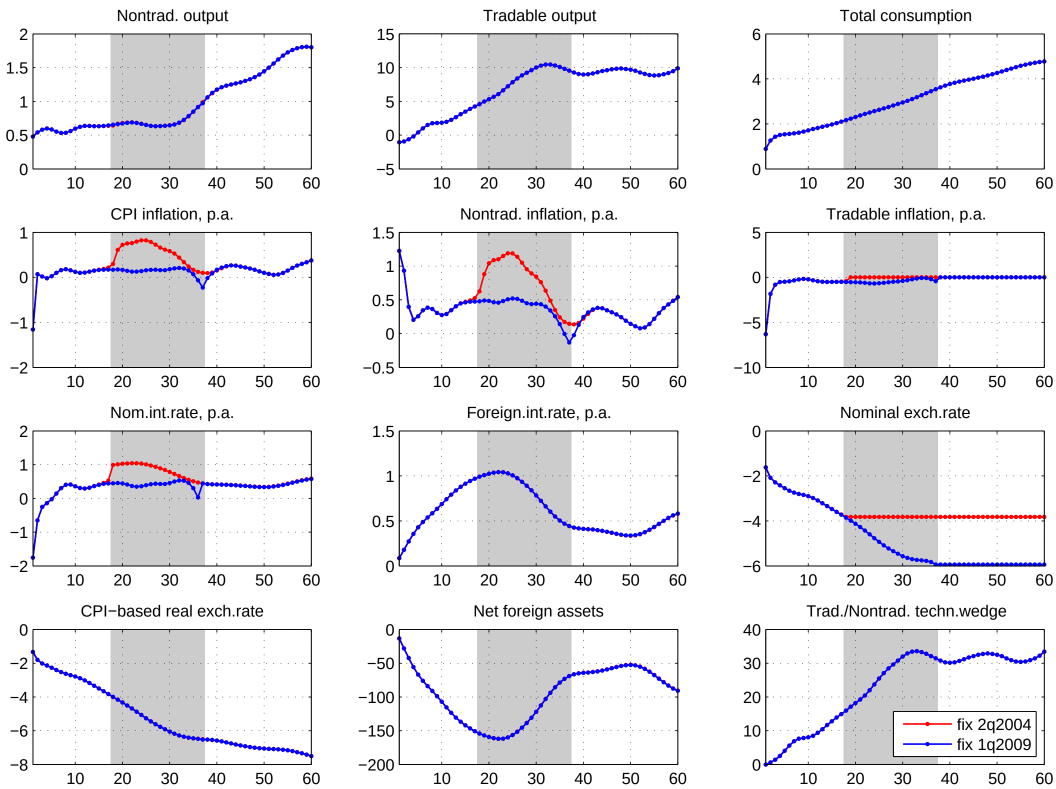


Figure 1.12: Different Timing of Transition with Future Productivity Path

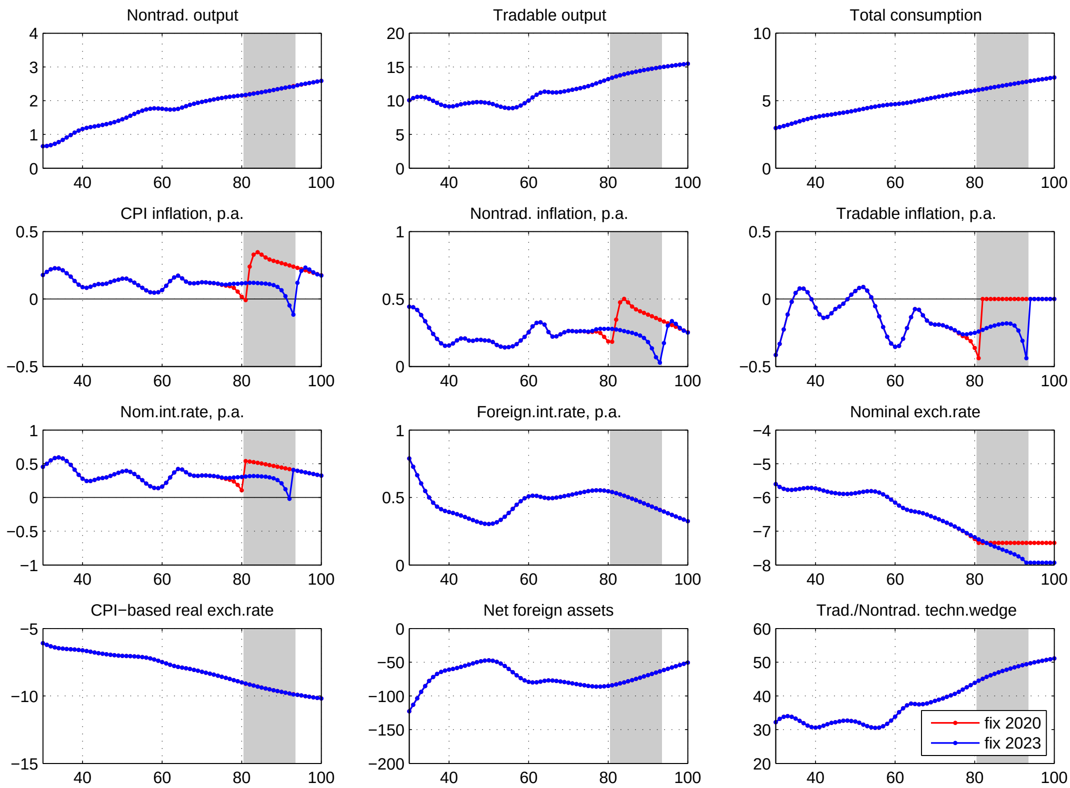


Figure 1.13: Euro Adopted by Surprise

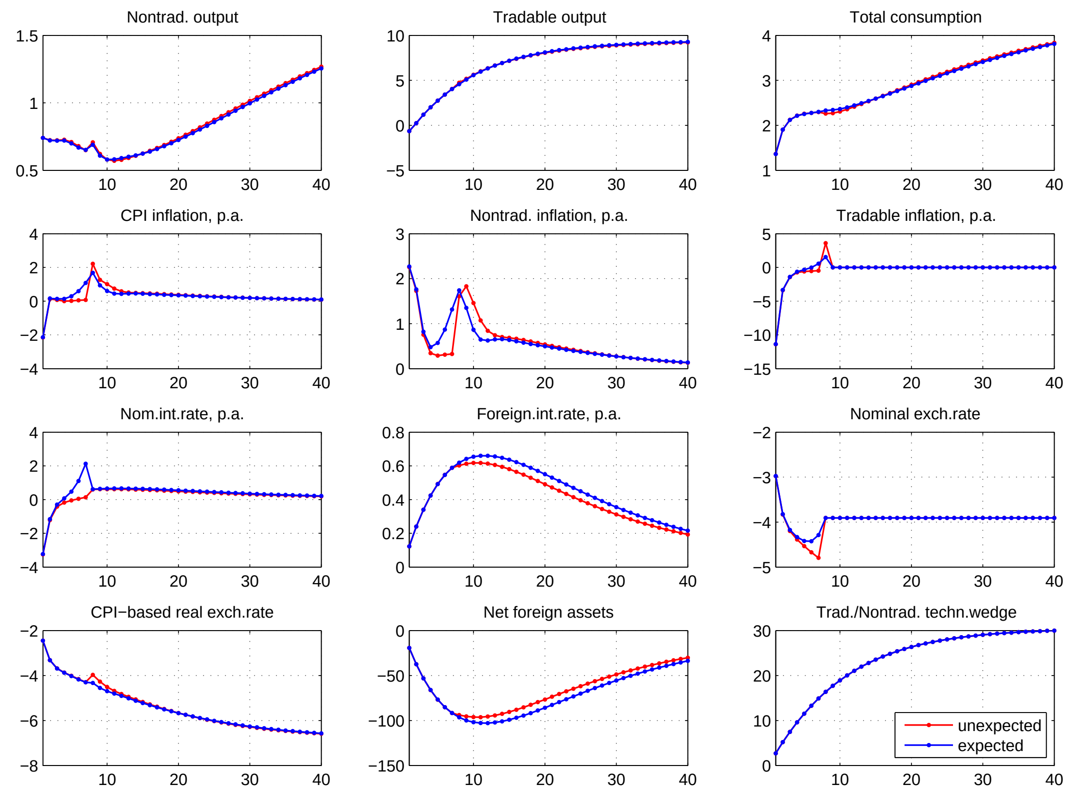


Figure 1.14: CPI Inflation, Decomposed into the Contributions of Structural Shocks

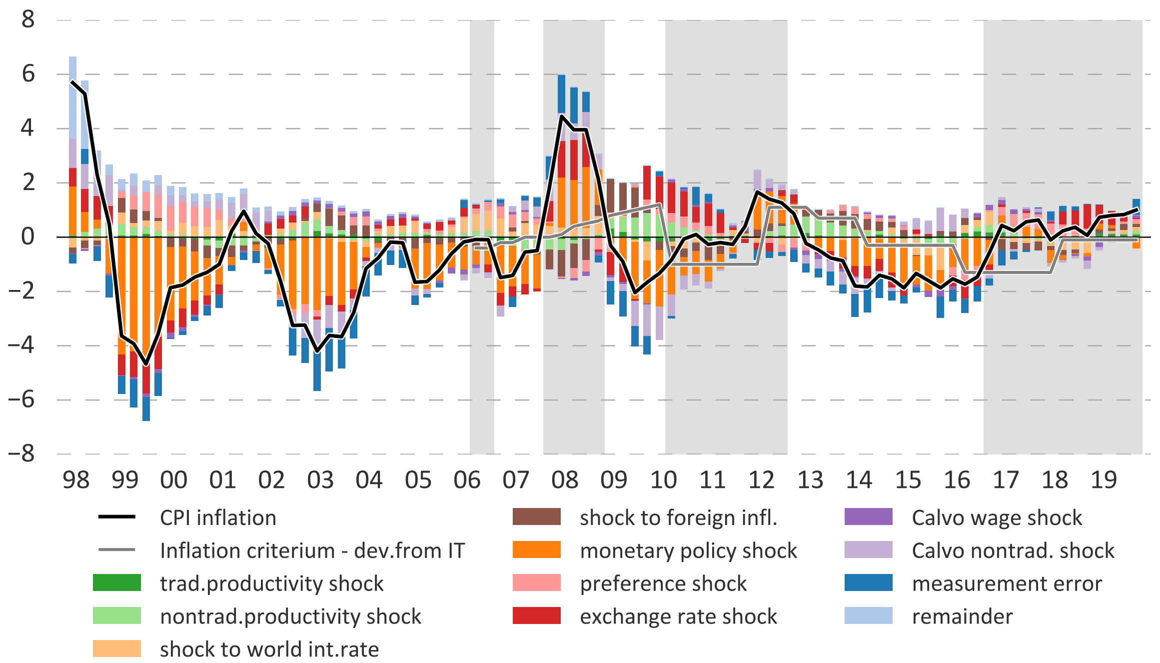


Figure 1.15: Nominal Exchange Rate, Decomposed into the Contributions of Structural Shocks

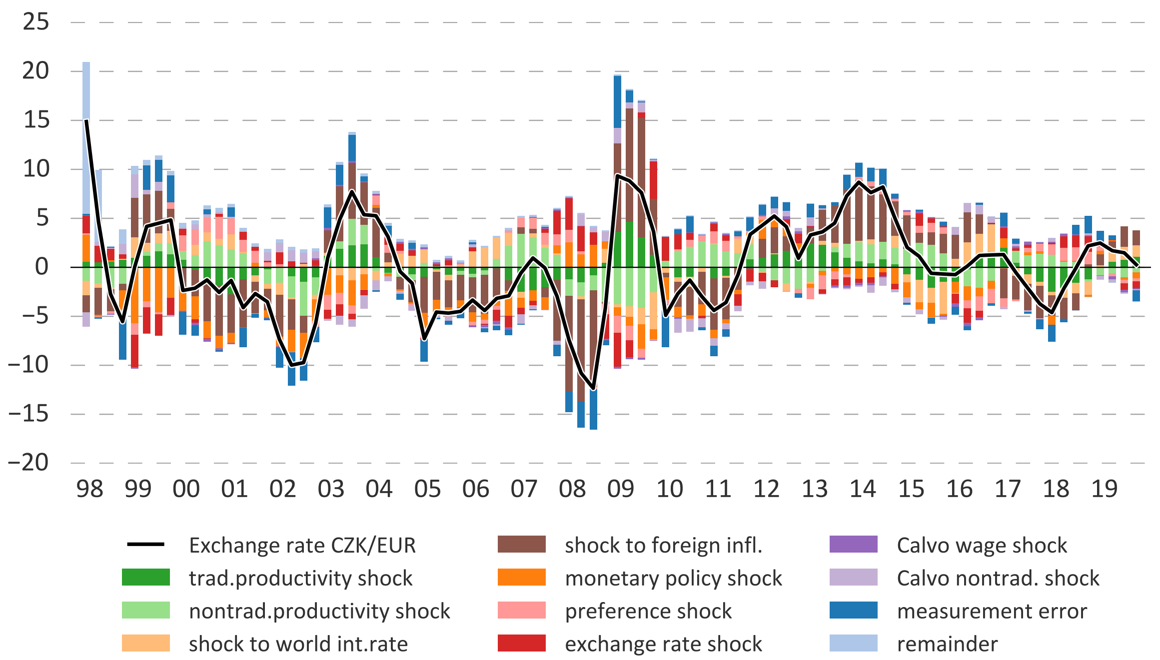


Figure 1.16: The Comparison of Stationary, Nonstationary and Nonlinear Simulations

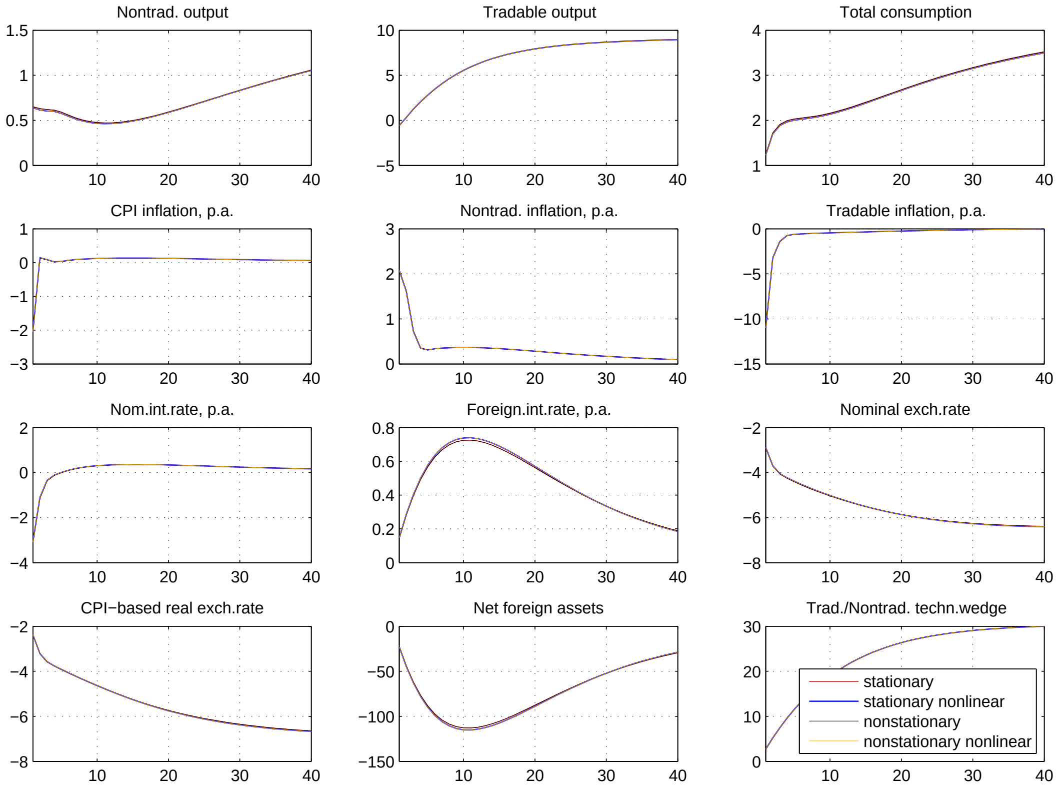


Figure 1.17: Sensitivity, Flexible Exchange Rate

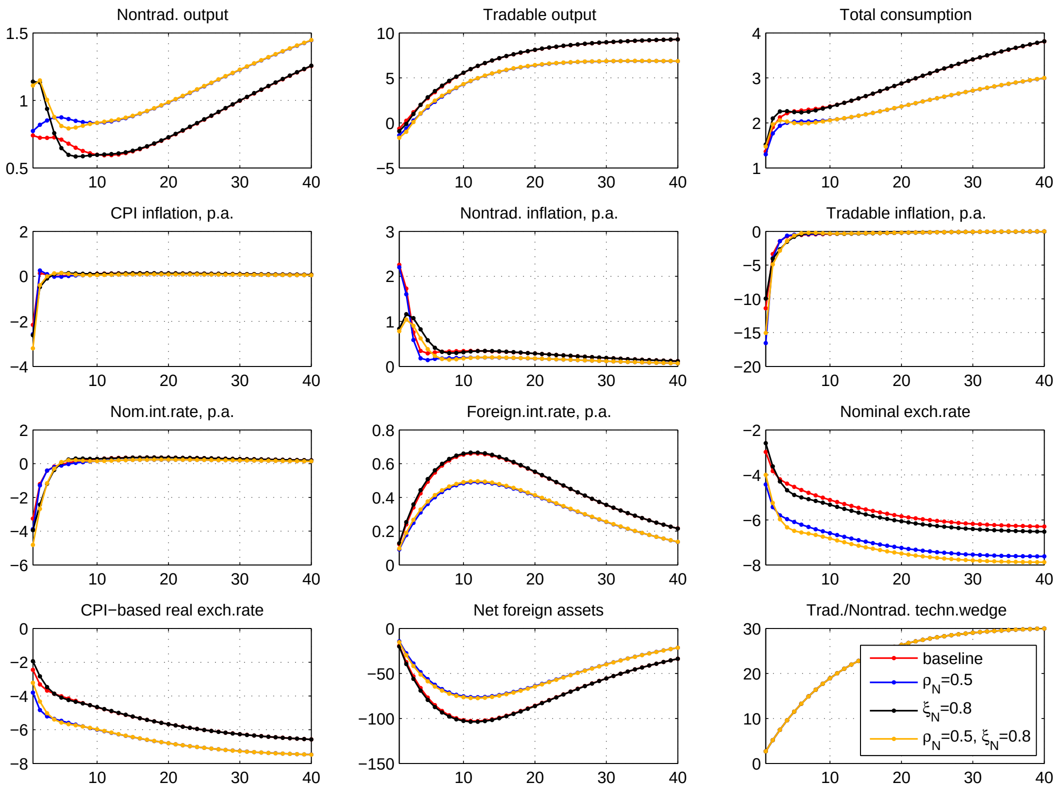
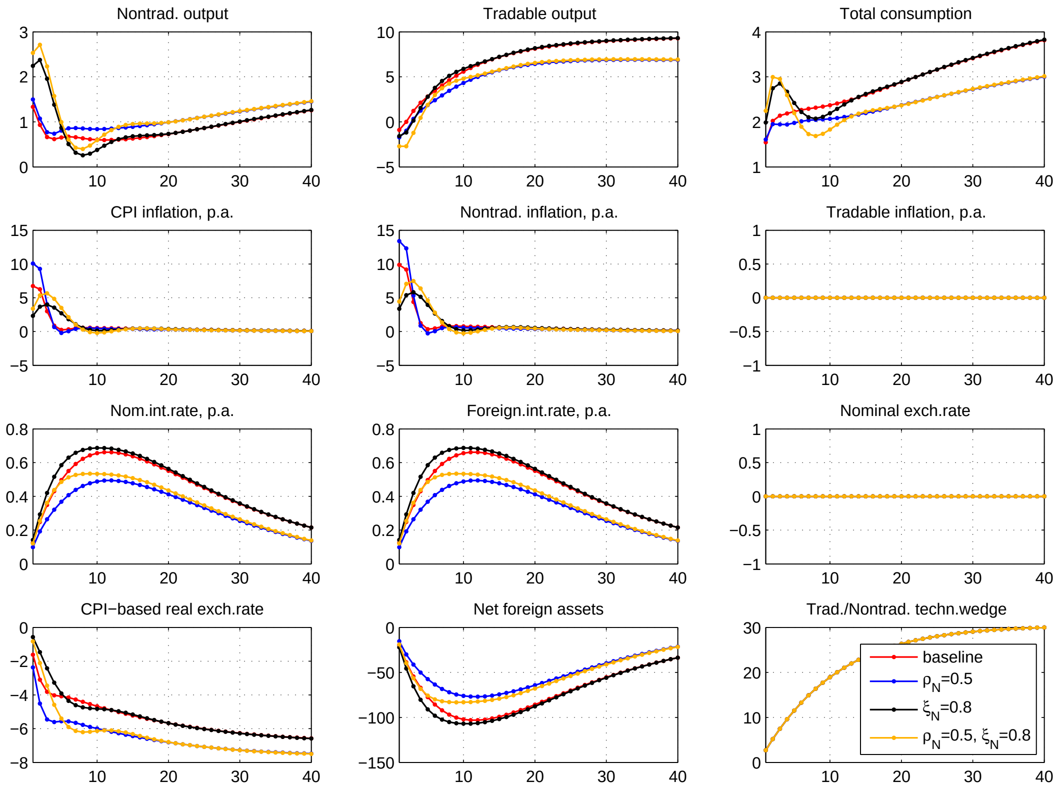


Figure 1.18: Sensitivity, Fixed Exchange Rate



Chapter 2

Growth-Friendly Fiscal Strategies for the Czech Economy[1]

2.1 Introduction

How fiscal policy is conducted has important repercussions on economic growth, which calls for adopting appropriate government decisions about a wide array of fiscal instruments, which are often set jointly, either to stimulate or restrain the economy. The government frequently 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 et al. 2015) where fiscal multipliers are used to rank fiscal

[1] This chapter is an updated version of Ambriško (2016): "Growth-Friendly Fiscal Strategies for the Czech Economy." CERGE-EI Working Papers wp563. The part of this chapter was also published as Ambriško (2019): "Fiscal Devaluation in an Small Open Economy." Russian Journal of Money and Finance 78(1). I am grateful to Jan Babecky, Michal Franta, Philipp Hartmann, Josef Hollmayr, Marek Kapicka, Michal Kejak, Marco Ratto, Marta Rodriguez-Vives, Jakub Rysanek, Sergey Slobodyan, Jan In't Veld, Milan Vyskrabka, and two anonymous referees for helpful discussions and suggestions. The model in this chapter benefited from comments at CNB seminars, and the UECE Conference on Economic and Financial Adjustments in Europe, Lisbon, 2013.

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.

Using its own set of fiscal multipliers, this research 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 a 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, what are the welfare effects of different fiscal instruments opposed to the output effects? Forth, could the Czech economy be better off with fiscal devaluation? What is the real GDP gain in such a case?

In addressing these research questions, I build a structural DSGE model, which is closely adapted from Ambriško et al. (2015). This model is essentially an extended version of the Czech National Bank's (CNB) g3 model (Andrle et al. 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 as proposed by Galí (2011), iv) a rich set of fiscal instruments on the revenue and expenditure side of the government budget, and v) estimated fiscal rules with feedback effects. The model is estimated by Bayesian techniques on Czech data over the 2000-2015 period, 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)[2]. 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[3]. 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 (16%) and social security contributions paid by employers (13%) are prescribed.

Besides the output effects, I also calculate welfare effects of different fiscal instruments. Welfare effects of fiscal stimulus imply different ranking of fiscal instruments. The largest welfare gains for the households are found in case of fiscal stimuli, which are based on cuts in taxes associated with wages (social contributions paid by employers and wage tax) or increases in government consumption.

Given the lack of empirical literature on fiscal devaluations for the Czech Republic, I use the model to evaluate the impact on the Czech economy of a hypothetical budget-neutral tax shift from direct to indirect taxes. The model's simulations show that the government can easily support the economy by adjusting the composition of taxes, from direct to indirect, appropriately. Specifically, real GDP growth can be boosted by 0.5 percentage points in the first year when a tax shift in magnitude of 1% of GDP occurs from direct to indirect taxes. If fiscal devaluation occurs in a hypothetical case of fixed exchange rate regime, the gain in real GDP growth is even larger, amounting 0.8 percentage points in the first year. Further, the model evaluates fiscal devaluation from the 2008 Stabilization Reform, finding positive real GDP gains from past tax changes.

This chapter is organized as follows. Section 2 reviews relevant literature, and Section

[2]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).

[3]Since the DSGE models have their limitations and are generally recommended for short and medium term analysis, the long-term growth-friendly fiscal strategies, mentioned later in the results, should be taken with caution.

3 outlines the structural DSGE model with an emphasis on fiscal features. Section 4 provides estimates of fiscal multipliers, derives appropriate growth-friendly fiscal strategies, evaluates welfare effects of different fiscal stimuli, and quantifies the impacts of hypothetical and past fiscal devaluation on the Czech economy. The last section summarizes the main findings and suggests several ideas for possible future research.

2.2 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 to the underlying model, which is well documented in a meta regression analysis by Gechert and Will (2012). The highest fiscal multipliers usually stem from macroeconometric models, while DSGE models tend to report the lowest multipliers. Nevertheless, the average fiscal multiplier across various types of models 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, is estimated in Hřebíček, Král, and Říkovský (2005) using both regression analysis and structural simulation. Prušvic (2010) ascertains 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), in which the authors calibrate the IMF's GIMF model for the Czech Republic and find the highest multipliers for government consumption and investment, both reaching 0.4. Using the SVAR model, Valenta (2011) estimates the fiscal multiplier for government spending in the range of 0.3–0.6. Franta (2012) employs various identification schemes in structural VAR models and calculates 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) apply the DSGE model from Ambriško et al. (2015) to generate the priors for the structural VAR model and obtain the highest fiscal multiplier for government investment, with a 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)[4] 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. Apart from focusing on fiscal consolidations, the ECB methodology can be easily extended in the case of fiscal stimulus, which is demonstrated in this study.

The literature on fiscal devaluations is rich, but currently lacks empirical evidence for the Czech Republic. The overview of quantitative studies on fiscal devaluations and its 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) assess 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) employ a partial equilibrium model to explore the likely effects of fiscal devaluations for seven countries in Southeastern Europe and find a positive impact on output growth of around 0.2 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. Contrary to the conventional view in the literature, Erceg, Prestipino, and Raffo (2018) note that fiscal devaluation might be contractionary on aggregate demand and inflation, especially under fixed exchange rates. Related to fiscal consolidation, there is a rich stream of trade literature, which examines import tariffs and export subsidies using DSGE models with several rigidities. For instance, Lindé

[4]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 Pescatori (2017) study the robustness of the Lerner symmetry[5] and find significant deviations from the symmetry if international asset markets are complete, there is a direct pass-through of tariffs and subsidies to prices, or exchange rate adjustment is gradual.

2.3 Structural DSGE Model

The structural model in this chapter is my simplified adaptation from Ambriško et al. (2015)[6], which further draws on the models developed by Andrle et al. (2009), Coenen, Straub, and Trabandt (2012), Galí (2011), and Galí, López-Salido, and Vallés (2007). The small open economy is populated by two types of representative households. The first type is households which can save, called optimizers or Ricardian households; the second type which cannot save and which consume all of their disposable income, called "rule-of-thumb" consumers or non-Ricardian households. The households consume a final consumption good, which is composed of 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.

There are several production sectors in the economy, with monopolistic firms producing intermediate domestic, consumption, investment, export, import and government goods. It is assumed that the pre-tax prices of consumption goods are rigid and that changes in consumption taxes are immediately and fully passed on to consumer prices[7]. Aside from private capital, there is government capital, which freely enters intermediate domestic goods production. Local currency pricing is assumed[8], which means that domestic importers take into account foreign prices and exchange rate movements to set sticky prices in domestic currency, whereas exporters' prices are sticky in foreign currency.

Government expenditures are divided into government consumption, government investment, unemployment benefits, and other social benefits. Government revenues come from consumption, labor, capital and lump-sum taxes, and social security contributions

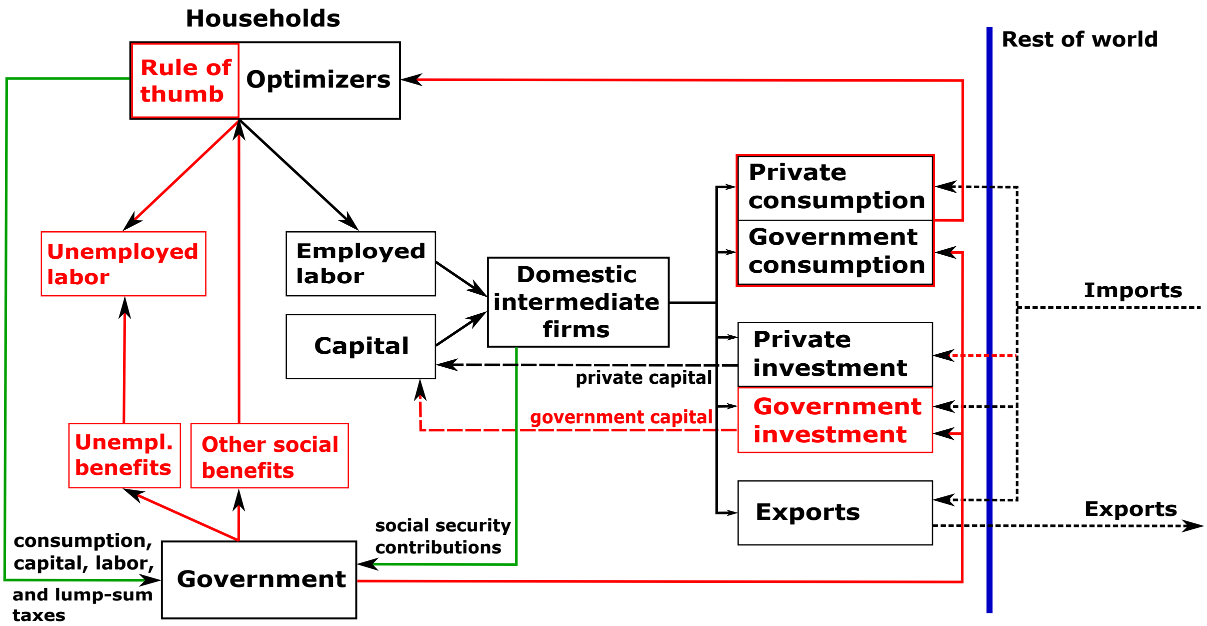
[5] Lerner (1936) demonstrates that combining an import tariff with an export subsidy should have an effect on the exchange rate such that price distortions from changes in trade policy are compensated and real allocations are unaffected.

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

[7] The empirical literature seems to be in favor of large and fast VAT pass-through into prices; for instance, the evidence for Eurozone countries can be found in Benedek et al. (2015).

[8] Most transactions in the Czech economy are denominated in Czech crowns. Currently around 20% of firms are estimated to make financial transactions in euros. Local currency pricing therefore seems justifiable.

Figure 2.1: The Scheme of the Model



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 2.1, 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 Appendix 2.A.

2.3.1 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 known 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:

$$
\begin{aligned}
E_0 \sum_{t=0}^{\infty} \beta^t U_{h,t}^k &= E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(C_{h,t}^k - \exp(\varepsilon_t^{hk}) \chi^k C_{t-1}^k) - \theta \int_0^1 \int_0^{L_t^k(i)} j^{\phi_n} dj di \right] = \\
&= E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(C_{h,t}^k - \exp(\varepsilon_t^{hk}) \chi^k C_{t-1}^k) - \frac{\theta}{1+\phi_n} \int_0^1 L_t^k(i)^{1+\phi_n} di \right]
\end{aligned} \tag{2.1}
$$

in which $\beta \in (0, 1)$ 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}^k is the lagged type-specific 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:

$$
C_t^k = \left[(\alpha_C)^{\frac{1}{v_C}} \left(C_t^{pk} \right)^{\frac{v_C - 1}{v_C}} + (1 - \alpha_C)^{\frac{1}{v_C}} \left(G_t^k \right)^{\frac{v_C - 1}{v_C}} \right]^{\frac{v_C}{v_C - 1}}, \tag{2.2}
$$

in which $\alpha_C \in (0, 1]$ is the share of the private good in the consumption aggregate, and $v_C > 0$ 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.

Optimizers households respect the following budget constraint:

$$
\begin{aligned}
& (1 + \tau_t^C) P_t^C C_t^{po} + P_t^I I_t^{po} + B_t^o \\
\leq\; & (1 - \tau_t^W + \tau_t^{UB}) \int_0^1 W_t(i) L_t^o(i) di + \\
& + \left[(1 - \tau_t^K) P_t^K + \tau_t^K \delta^p P_t^I \right] K_{t-1}^{po} + \\
& + R_{t-1} B_{t-1}^o + P_t^C OB_t^o - P_t^C T_t^o + D_t^o,
\end{aligned} \tag{2.3}
$$

in which 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 the 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):

$$K_t^{po} = \left(K_{t-1}^{po}\right)^{1-\delta^p} \left(\frac{I_t^{po}}{\delta^p}\right)^{\delta^p} - \frac{\eta}{2}\left(\frac{I_t^{po}}{I_{t-1}^{po}} - 1\right)^2 K_{t-1}^{po}, \tag{2.4}$$

in which $\eta \geq 0$ 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:

$$\begin{aligned}(1+\tau_t^C)P_t^C C_t^{pr} \quad &\leq \quad (1-\tau_t^W+\tau_t^{UB})\int_0^1 W_t(i)L_t^r(i)di + \\ &+P_t^C OB_t^r - P_t^C T_t^r, \end{aligned} \tag{2.5}$$

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

2.3.2 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:

$$\begin{aligned}BB_t \quad = \quad &\tau_t^C P_t^C C_t^p + \left(\tau_t^W + \tau_t^S\right) W_t L_t + \tau_t^K \left(P_t^K - \delta^p P_t^I\right) K_{t-1}^p + \\ &+P_t^C T_t - P_t^G G_t - P_t^I I_t^g - \tau_t^{UB} W_t L_t + \\ &-P_t^C OB_t - (R_{t-1}-1)B_{t-1}, \end{aligned} \tag{2.6}$$

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

$$PB_t = BB_t + (R_{t-1} - 1)B_{t-1} \tag{2.7}$$

The government's budget constraint follows:

$$B_{t-1} - BB_t = R_{t-1}B_{t-1} - PB_t = B_t \tag{2.8}$$

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:

$$K_t^g = \left(K_{t-1}^g\right)^{1-\delta^g} \left(\frac{I_t^g}{\delta^g}\right)^{\delta^g} - \frac{\eta}{2}\left(\frac{I_t^g}{I_{t-1}^g} - 1\right)^2 K_{t-1}^g, \tag{2.9}$$

in which $\delta^g > 0$ 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):

$$K_t = \left[(\alpha_K)^{\frac{1}{v_K}} \left(K_t^p\right)^{\frac{v_K-1}{v_K}} + (1-\alpha_K)^{\frac{1}{v_K}} \left(K_t^g\right)^{\frac{v_K-1}{v_K}}\right]^{\frac{v_K}{v_K-1}}, \tag{2.10}$$

in which $\alpha_K \in [0, 1]$ 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 using fiscal rules. All fiscal instruments react to deviations of output and real debt from their steady states. Unemployment benefits also respond to deviations of the 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:

$$\begin{aligned}
\frac{G_t}{\bar{G}} &= \left(\frac{G_{t-1}}{\bar{G}}\right)^{\rho_g} \left(\frac{Y_t}{\bar{\bar{Y}}}\right)^{-\phi_{yg}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{bg}} \exp(\varepsilon_t^g) \\
\frac{I_t^g}{\bar{I}^g} &= \left(\frac{I_{t-1}^g}{\bar{I}^g}\right)^{\rho_{ig}} \left(\frac{Y_t}{\bar{\bar{Y}}}\right)^{-\phi_{yig}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{big}} \exp(\varepsilon_t^{ig}) \\
\frac{\tau_t^{UB}}{\bar{\tau}^{UB}} &= \left(\frac{\tau_{t-1}^{UB}}{\bar{\tau}^{UB}}\right)^{\rho_{ub}} \left(\frac{Y_t}{\bar{\bar{Y}}}\right)^{-\phi_{yub}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{bub}} \left(\frac{u_t}{\bar{u}}\right)^{\phi_u} \exp(\varepsilon_t^{ub}) \\
\frac{OB_t}{\bar{OB}} &= \left(\frac{OB_{t-1}}{\bar{OB}}\right)^{\rho_{ob}} \left(\frac{Y_t}{\bar{\bar{Y}}}\right)^{-\phi_{yob}} \left(\frac{b_t}{\bar{b}}\right)^{-\phi_{bob}} \exp(\varepsilon_t^{ob})
\end{aligned} \tag{2.11}$$

$$
\begin{aligned}
\frac{\tau_t^C}{\bar{\tau}^C} &= \left(\frac{\tau_{t-1}^C}{\bar{\tau}^C}\right)^{\rho_{tc}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{ytc}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{btc}} \exp(\varepsilon_t^{tc}) \\
\frac{\tau_t^K}{\bar{\tau}^K} &= \left(\frac{\tau_{t-1}^K}{\bar{\tau}^K}\right)^{\rho_{tk}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{ytk}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{btk}} \exp(\varepsilon_t^{tk}) \\
\frac{\tau_t^W}{\bar{\tau}^W} &= \left(\frac{\tau_{t-1}^W}{\bar{\tau}^W}\right)^{\rho_{tw}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{ytw}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{btw}} \exp(\varepsilon_t^{tw}) \\
\frac{\tau_t^S}{\bar{\tau}^S} &= \left(\frac{\tau_{t-1}^S}{\bar{\tau}^S}\right)^{\rho_{tw}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{yts}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{bts}} \exp(\varepsilon_t^{ts}) \\
\frac{T_t}{\bar{T}} &= \left(\frac{T_{t-1}}{\bar{T}}\right)^{\rho_{t}} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_{yt}} \left(\frac{b_t}{\bar{b}}\right)^{\phi_{bt}} \exp(\varepsilon_t^{t})
\end{aligned} \tag{2.12}
$$

in which 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 normally distributed 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:

$$T_t^o - \bar{T}^o = T_t^r - \bar{T}^r \tag{2.13}$$

2.3.3 Calibration

The parameters of the model were either calibrated or estimated on Czech data. In this section, the calibrated parameters of the model are described. For the purposes of comparison, the calibration is mostly as in Andrle et al. (2009). The complete list of calibrated parameters and steady state ratios can be found in Table 2.1 in the Appendix.

The 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 the 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 2.3.4. Other fiscal parameters were estimated; this concerns mainly output and debt feedback parameters in the fiscal rules. Nonetheless, the posterior mean of the debt feedback coefficient for consumption tax ϕ_{btc} turned out quite high (0.39), and for more reasonable impulse responses to the consumption tax shock, this debt feedback parameter was calibrated to a 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 is set to 25%, the proportion of government investment in output is 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; 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 is set to 15%, while 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 the shares observed 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 a plausible mark-up for European economies; for instance, Christopoulou and Vermeulen (2012) estimate the average markup for the manufacturing sector at 20% in selected European countries over the 1993–2004 period. The elasticity between labor varieties is determined from equation (2.55) – 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 translates 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), in which he finds 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 literature on the real business cycle. 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 their different degree of historical variability. UIP sluggishness is set so as to generate a more realistic response by nominal exchange rate to 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.

2.3.4 Data

The model is estimated on a set of 25 variables, covering the 2000–2015 period 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, the 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, the 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 and for domestic and foreign interest rates were not seasonally adjusted. An overview of the data and their respective sources is available in Table 2.2 in the Appendix.

Effective tax rates were constructed from the CZSO data, using a slightly adjusted methodology suggested by Mendoza, Razin, and Tesar (1994)[9]. The effective tax rate on consumption is constructed as follows:

$$\tau_t^C = \frac{IT_t - IT_t^K}{C_t^{np} + G_t^n - CoE_t - (IT_t - IT_t^K)}, \tag{2.14}$$

in which 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 is the compensation of government employees. 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:

$$\tau_t^S = \frac{SCE_t}{W_t}, \tag{2.15}$$

in which 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:

$$\tau_t^W = \frac{DT_t - DT_t^K + SCH_t}{W_t}, \tag{2.16}$$

in which 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[10]), 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:

$$\tau_t^K = \frac{CT_t + IT_t^K + DT_t^K}{NOS_t}, \tag{2.17}$$

in which 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

[9] I also 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.

[10] Real property tax is recorded under both direct and indirect taxes, with the majority appearing under indirect taxes.

operating surplus. All of the above effective tax rates are shown in Figure 2.2 in the Appendix.

Unemployment benefits were gathered from the MoF cash data, and adjusted into accrual terms by shifting paid benefits back one month (e.g. unemployment benefits paid in January correspond to the previous month, when the individual in question 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 investment. Private investment is subsequently calculated as the difference between real total investment and real government investment.

2.3.5 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 1/4 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 is the case for 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[11]. 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[12]. The prior mean for the elasticity of the marginal disutility of work ϕ_n equals 2.5. The prior mean for the inflation feedback

[11] The selected mean of the distribution is justified by a Gallup poll, in which 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.

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

coefficient is calibrated at 2. The prior means for the debt feedback coefficients in the fiscal rules all equal 0.25, for which a guaranteed stable solution of the model exists. 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 may be pro- or counter-cyclical. The prior mean for the unemployment feedback coefficient is set at 1 to reflect that unemployment benefits should move in line with the unemployment rate.

A DYNARE toolbox for MATLAB was employed for Bayesian estimation of the selected parameters.[13] Given the priors chosen and the data observed, 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 2.3–2.6 in the Appendix show priors and posterior distributions and the results of the multivariate convergence diagnostic test.

The estimation results are also summarized in Table 2.3 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. As for monetary policy, the posterior mean for the inflation feedback coefficient in the policy rule ϕ_π is found to be 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. This 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 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 helps to stabilize government debt outside of equilibrium and leads

[13]For details of the toolbox see www.dynare.org.

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.

2.3.6 Steady State

The steady state of the model is computed on the basis of the calibrated and estimated[14] parameters of the model. 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, steady state values for all the model variables can be computed numerically. The system of optimality conditions is then log-linearized around the steady state and solved using the IRIS toolbox.[15]

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 steady state consumption ratio is achieved 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.

2.4 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 strategies. In addition to the output effects, welfare effects of different fiscal stimuli are computed as well. Finally, the model is used to evaluate the likely impacts of past and hypothetical fiscal devaluations, meaning a shift from direct to indirect taxation.

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

[15]IRIS is a toolbox for macroeconomic modeling and forecasting in MATLAB developed by Beneš (2014). Further information on the IRIS toolbox is available at www.iris-toolbox.com.

2.4.1 Fiscal Multipliers

Impact fiscal multipliers are defined as follows:

$$fm_{i,t} = \frac{\frac{\Delta RGDP_t}{RGDP}}{\frac{\Delta\left(F_t P_t^F\right)}{GDP}} \tag{2.18}$$

in which F_t denotes the selected fiscal instrument and P_t^F its price. The numerator 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 as a percentage of the nominal GDP in the steady state. Exact expressions for fiscal revenues or expenditures can be drawn from the equation for the government budget balance (2.6); 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 2.4 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:

$$fm_{i,T} = \frac{\sum_{t=1}^{T} \frac{\Delta RGDP_t}{RGDP\left(\overline{R}\right)^t}}{\sum_{t=1}^{T} \frac{\Delta\left(F_t P_t^F\right)}{GDP\left(\overline{R}\right)^t}} \tag{2.19}$$

Notice that this kind of fiscal multiplier can be interpreted as the average discounted change in real GDP over the average discounted change in fiscal revenue/expenditure. Fiscal multipliers are listed with their 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) in order to isolate the effects of affected fiscal instruments.[16] Immediately turning on the fiscal rule would mean that the feedback effects defined in the fiscal rule would somewhat blur the results. The

[16] The choice of two years is motivated by Coenen, Straub, and Trabandt (2013), who assume accommodative fiscal policy for an initial two years. These authors argue that this approach more closely resembles the policy actions in response to the financial crisis.

estimated fiscal rule is treated as a good approximation of the fiscal policy settings in the long run; so 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 the issue of 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 (2.11)–(2.12). Nevertheless, at the end of this section, the fiscal multipliers with fully operational fiscal rule are presented as well, which includes the effects of so-called automatic stabilizers on top of unexpected changes in fiscal instruments.

The Analysis of Impulse Response Functions

The transmission mechanism of one-year fiscal shocks on the economy are depicted in Figures 2.7–2.8 in the Appendix, for both government spending and tax shocks. To make the fiscal simulations comparable, fiscal shocks are calibrated so that the change of the government budget balance in the first year equals 1% of GDP. The values of temporary fiscal multipliers are then based on these simulations.

Spending Shocks. Referring to Figure 2.7, several similar patterns can be identified when inspecting the shocks to government consumption (in red lines), government investment (in blue), unemployment benefits (in black), and other social benefits (in yellow). All spending shocks raise real GDP, but to different extents. Demand pressures, stemming from additional government spending, induce firms to produce more. So firms need more labor inputs and the unemployment rate drops. The real marginal costs of firms producing domestic intermediate goods increase. This translates into higher CPI inflation, to which the central bank reacts by raising the nominal interest rate. As a result of higher government spending, which is financed by issuing new debt, the government budget balance worsens.

On the other hand, there are some significant differences between the effects of the four government spending instruments with respect to total consumption. Government consumption, unemployment benefit, and other social benefit shocks raise total consumption in the economy, whereas an increase in government investment crowds out total consumption. For the government consumption shock the nominal exchange rate appreciates, but in the case of the government investment shock the nominal exchange rate depreciates. This is because government investment goods also have a foreign component, while for the production of government consumption goods only domestic inputs are needed. Next, the trade balance worsens in the case of government investment shock, but for government consumption shock it improves slightly. The channels underlying the change in trade balance are therefore different: a similar decrease in both exports and imports in reaction to the government consumption shock, and an improvement in both exports and imports (the rise in imports being stronger) following the government investment shock.

The responses of unemployment benefits and other social benefits are qualitatively very similar. This is given by their construction, as they similarly enter the budget constraint of households and the only difference resides in the specification of the fiscal rule for unemployment benefits, which react to unemployment fluctuations, whereas other social benefits do not. For both shocks, the nominal exchange rate depreciates slightly in the first year, which supports exports. Imports also rise due to increased demand, and the overall trade balance initially worsens. Notice that a positive demand effect is the main channel through which an increase in unemployment benefits and other social benefits leads to a decrease in unemployment.

Altogether, the highest effects on real GDP occur with the shocks to government consumption, followed by government investment, unemployment benefits and other social benefits. An explanation for this ranking can be found from impulse responses, focusing particularly on the expenditure components of real GDP. Although government consumption crowds out private consumption, it has the highest effect on total consumption. At the same time, government consumption encourages private investment, and due to the production process, where only domestic goods are used in making government consumption goods, the contribution of net exports turns positive. Government investment shock induces the highest effects on total investment, but significantly crowds out total consumption. Due to the foreign component of investment goods, the contribution of government investment shock to net exports is negative. Contrary to government consumption and investment shocks, both unemployment benefits and other social benefits' shocks support private consumption, but the overall effect on total consumption is somewhat smaller than that of the government consumption shock. Since private consumption also contains a foreign component, the contribution of net exports is negative for unemployment benefits and other social benefits, in contrast to government consumption. The slightly better ranking of unemployment benefits against other social benefits can mainly be attributed to more pronounced effects of unemployment benefits shock on private consumption and exports.

Tax Shocks. Looking through Figure 2.8, the model allows us to examine the effects of five tax shocks: the consumption tax shock (in blue lines), wage tax shock (in gray), social security contribution tax shock (in orange), capital tax shock (in light blue), and lump-sum tax shock (in red). As expected, higher tax revenues improve the government budget balance and lower the government debt. Any positive tax shock in the model causes real GDP to decline. Except for social security contributions paid by employers, taxes directly affect households' budget constraints. On the other hand, social security contributions paid by employers increase labor costs in production, firms reduce their demand for labor, and households' income shrinks along with their lower wage income.

Except for capital tax shock, higher taxes decrease households' disposable income, leading to a drop in consumption. The decrease in consumption induces firms to demand less labor; hence the unemployment rate increases and real wages fall. On the other hand, a hike in capital tax depresses investment, but consumption crowds in and remains roughly stable in the initial two years. Except for social security contributions, higher taxes cause real marginal costs to decrease mildly. The central bank responds to disinflationary pressures by lowering the nominal interest rate. With higher social security contributions the inflation rate rises, and is dampened by the reaction of the central bank.

The nominal exchange rate tends to appreciate with hikes in the taxes, although there is an initial minor depreciation for consumption and lump-sum taxes. This appreciation contributes to a decline in exports. Except for social security contributions, disinflationary pressures cause a substitution in consumption from foreign to domestic goods. Thus, imports also decrease, and the trade balance improves (for capital tax shock it stays roughly stable). For the shock to social security contributions, the nominal exchange rate appreciation is high enough to induce higher imports, worsening the trade balance.

Comparing all tax shocks, social security contributions have the highest effects on real GDP, followed by wage tax, consumption tax, lump-sum tax, and capital tax. The social security contributions shock is proinflationary, worsening the international competitiveness of domestic firms, and thus suppressing exports. Due to higher CPI prices imports rise, and the trade balance deteriorates significantly. Total consumption is also hit negatively, but to a somewhat smaller extent than in the case of consumption or wage tax shocks. Because of the disinflationary nature of other tax shocks than the social security contributions shock, the contribution of net exports to real GDP growth is positive (or roughly neutral for capital tax shock), which mutes the negative contribution of total consumption affected by these tax shocks. The responses of both consumption and wage tax shocks on real GDP are very similar in the first year; nevertheless, the consumption tax has a more negative effect on private consumption, whereas a drop in the wage tax boosts more private investment. The lump-sum tax shock has relatively milder negative impact on labor supply, which manifests in a smaller decrease of total consumption compared to consumption or wage tax shocks. The capital tax shock has the lowest impact on real GDP, reflecting its roughly neutral effect on consumption and trade balance, accompanied by a negative contribution to private investment, which is the highest of all taxes considered in the first two years.

The Values of Fiscal Multipliers

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 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 is the lowest, at 0.1. All values for fiscal multipliers with effects on real GDP are well below 1. The ranking of fiscal multipliers reflect impulse responses shown in Figures 2.7–2.8 and described in detail in the previous section.

The values of fiscal multipliers for government consumption and investment are not far from the CNB estimates of around 0.6 reported in Hřebíček, Král, and Říkovský (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 estimates 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 than their estimates (0.6 and 0.5, compared to 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 study 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, Straub, and Trabandt (2012) for the Euro Area (0.03–0.06).

Lastly, I compare the values of fiscal multipliers in this study to those found in Ambriško et al. (2015). As I mentioned above, these two works share a similar model. Some fiscal multipliers in this study are higher (consumption and wage tax, lump-sum tax, unemployment benefits and other social benefits), which is explained by the higher estimated share of "rule-of-thumb" households in this study. On the other hand, the fiscal multiplier for social contributions paid by employers is lower in this study (in the first year 0.4 vs. 0.6), which is largely the result of the lower calibrated value for the persistence of social contributions in this study. Fiscal multipliers for government consumption and government investment attain roughly same values in the short run in both studies.

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. It is important to note that the calculated values of fiscal multipliers should be taken as average fiscal multipliers over the business cycle, holding for the economy under normal conditions and neglecting any nonlinearities (such as the zero lower bound on interest rates). Generally, fiscal multipliers depend on many specific assumptions made in the models. For example, Leeper, Traum, and Walker (2017) present a thorough summary of which aspects drive fiscal multipliers, showing that essential assumptions include: the degree of nominal and real rigidities, the productivity of government spending besides private consumption, the prevailing monetary-fiscal policy regime, the presence of distorting steady-state taxes, the level and maturity structure of outstanding government debt, pegging the interest rate (at the effective lower bound), and the position over the business cycle. In addition, there exist another relevant drivers of fiscal multipliers: the share of rule-of-thumb households, the specification of the fiscal rule, the elasticity of labor supply or the anticipation of fiscal shocks (Ambriško et al. 2015).

The fiscal multipliers for a 10-year fiscal stimulus have similar values in the short run to the multipliers for 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.

The fiscal multipliers with a fully operational fiscal rule are shown in Table 2.5 in the Appendix. In contrast to the baseline, where the fiscal rule is initially turned off for two years, these fiscal multipliers are constructed under the assumption of a fully operational fiscal rule for the whole simulation period. Thus, unexpected changes in the fiscal instruments are accompanied by so-called automatic stabilizers, which are present in the fiscal rule. The highest fiscal multipliers for a 1-year fiscal stimulus are found for government consumption (0.5), followed by government investment (0.3), and social contributions paid by employers and consumption tax (0.2). Compared to the baseline results, the fiscal multipliers attain lower values, which is mainly for the following reasons. Fiscal stimulus – a sudden increase in government expenditure or decrease in taxes – induces higher government indebtedness. Since the debt feedback parameters are positive in the fiscal rule, such fiscal stimulus immediately triggers partial counter-movement[17] (i.e. fiscal austerity) in other fiscal instruments, to finance higher government debt – there is a decrease in government expenditures and an increase in taxes. Therefore, the effect of a fiscal stimulus on real GDP is partially muted by built-in automatic stabilizers, which are present in the fiscal rule. This result is in line with Caldara and Kamps (2017), who prove that in SVAR models the relationship between the size of the systematic response in the fiscal policy rule and the fiscal multiplier is negative. Note that there is a negative fiscal multiplier for capital tax, which is the result of the systematic response of other fiscal instruments (cuts in government expenditure and hikes in other taxes) to the unexpected decrease in capital tax. For the transmission mechanism and the differences with respect to the baseline see the impulse reaction functions for capital tax in Figure 2.9. The red lines depict the simulation with a fully operational fiscal rule, whereas the blue lines represent the case with the fiscal rule temporarily turned off for two years.

2.4.2 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

[17] These immediate counter-movement effects are not present in the baseline results, because the fiscal rule is temporarily turned off for initial two years.

security contributions paid by employers. For a longer-lasting fiscal stimulus[18], 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 an 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 that proposed by Drudi et al. (2015). The underlying idea is that, during consolidations, the fiscal instruments that are the most detrimental to the economy are penalized, and consequently in the composition of fiscal consolidation, they are represented with a lower share. Similarly, during fiscal stimulus, the fiscal instruments that are the most beneficial to the economy are prioritized, and in the composition of fiscal stimulus, they gain a higher share.

Fiscal Consolidation

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

$$fs_{i,T}^{cons} = \frac{fm_T^{\max} - fm_{i,T}}{fm_T^{\max} - fm_T^{\min}}, \tag{2.20}$$

in which 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

[18]Due to the limitations of the DSGE models and their better performance in the short and medium term, the suggested longer-lasting growth-friendly fiscal strategies should be taken with some caution.

(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; i.e., 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 2.6 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 2.8–2.9 in the Appendix. The lump-sum taxes were removed from the composition, as these are not prevalent 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%). If 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.

Fiscal Stimulus

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

$$fs_{i,T}^{stim} = \frac{fm_{i,T} - fm_T^{\min}}{fm_T^{\max} - fm_T^{\min}} \tag{2.21}$$

The highest fiscal score is attached to the fiscal instrument, which attains the highest fiscal multiplier; i.e. it has the largest impact on real GDP growth during fiscal stimulus. Fiscal scores for fiscal stimulus are provided in Table 2.7 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 2.8–2.9 in the Appendix.

Regarding 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. In addition to 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.

It is important to note that one of the main determinants of the composition of fiscal strategy (either for fiscal consolidation or fiscal stimulus) are the shares of fiscal revenues and expenditures in GDP. These shares are country specific and set according to the model's implied shares of fiscal revenues/expenditures to nominal GDP, which are given by the calibrated and estimated parameters of the model. If, in reality, some fiscal shares shift substantially due to the changes in fiscal policy, then it is highly advised to redo the calibration and estimation of the model to derive a new composition of the fiscal strategy. Furthermore, the composition of the fiscal strategy is also determined by the assumption made on the construction of fiscal scores (defined in 2.20–2.21). For instance, if the linear nature of fiscal scores is altered in favor of a more strict penalization of detrimental fiscal instruments, then this would be reflected in the composition of the fiscal strategy, assigning larger shares to more growth-friendly fiscal instruments.

2.4.3 Welfare Effects of Fiscal Instruments

So far, fiscal instruments have been evaluated through the effects of fiscal stimulus or fiscal consolidation on real GDP. Nonetheless, policymakers should also care about the welfare effects of fiscal policies, because these may differ from the output effects. Although a fiscal policy may result in output gains, the impact on welfare might be more complex, depending on the reaction of labor supply and consumption. For example, in the case of fiscal stimulus the real GDP growth may be driven mainly by the increase in employed labor and less by the rise in consumption. Thus, welfare gains could be lower than the output gains.

Following Schwarzmüller and Wolters (2014), I calculate the welfare effects of different fiscal instruments. The welfare of the households V_t^k is derived from their utility functions:

$$V_t^k = E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(C_t^k - \chi^k C_{t-1}^k) - \frac{\theta}{1+\phi_n} \left(L_t^k\right)^{1+\phi_n} \right], \tag{2.22}$$

in which superscript $k \in \{r, o\}$ distinguishes rule-of-thumb and optimizer households. Due to evaluating welfare at optimizing paths, the expression for welfare is a simplified version of the utility functions (Equation 2.1), dropping the indices h and i and the stochastic shock to habit formation ε_t^{hk}. Aggregate welfare is the weighted average of welfare for rule-of-thumb and optimizer households:

$$V_t = \gamma V_t^r + (1-\gamma) V_t^o \tag{2.23}$$

The welfare effects of fiscal instruments are calculated as follows. Different fiscal stimulus policies affect the households' trajectories C_t^k and L_t^k, which are fed into the expression for welfare 2.22. Because of the timeless perspective, welfare effects are solved backwards. The expression for welfare can be recursively written as:

$$V_t^k = \log(C_t^k - \chi^k C_{t-1}^k) - \frac{\theta}{1+\phi_n} \left(L_t^k\right)^{1+\phi_n} + \beta E_t V_{t+1}^k \tag{2.24}$$

Under the perfect foresight assumption, one can calculate at time $t = 1$ the welfare V_1^k for both types of households, which takes into account households' decisions about consumption and leisure for all periods ($t = 1, ..., \infty$). Aggregate welfare at the same time equals $V_1 = \gamma V_1^r + (1-\gamma) V_1^o$.

Since these welfare measures are difficult to interpret, welfare effects are usually transformed into so-called consumption equivalence units, computed in line with Schmitt-Grohe and Uribe (2006). Consumption equivalence units state the amount of the permanent change in consumption that leads to the same welfare achieved with specific fiscal stimulus. Consumption equivalence units λ^k for both types of households can be computed from the following relationship:

$$V_1^k = \frac{1}{1-\beta} \left[\log(1-\chi^k)(1+\lambda^k)\overline{C}^k - \frac{\theta}{1+\phi_n} \left(\overline{L}^k\right)^{1+\phi_n} \right], \tag{2.25}$$

in which $\overline{C}^k$ and $\overline{L}^k$ are the steady states for consumption and labor supply of respective households type. Rearranging this expression, consumption equivalence units equal:

$$\lambda^k = \frac{\exp\left[(1-\beta) V_1^k + \frac{\theta}{1+\phi_n} \left(\overline{L}^k\right)^{1+\phi_n} \right]}{(1-\chi^k)\overline{C}^k} - 1 \tag{2.26}$$

Finally, the aggregate consumption equivalence unit is the weighted sum $\lambda = (1-\gamma)\lambda^o + \gamma \lambda^r$.

The welfare effects of fiscal stimulus[19] for different fiscal instruments that result from

[19]Fiscal stimulus is simulated in the same manner as in the analysis of fiscal multipliers presented in Section 2.4.1.

my model, are shown in Table 2.10 in the Appendix. These welfare effects are expressed in consumption equivalence units for aggregate, optimizer and rule-of-thumb households. The one-year fiscal stimulus aggregate welfare effects range from -0.00027 for government investment to 0.00013 for social contributions paid by employers. These numbers seem relatively low, but one has to bear in mind that fiscal stimulus is only temporary and lasts one year, whereas consumption equivalence units represent the permanent change in consumption that lasts for all periods. Except for government investment and capital tax, fiscal stimulus with other fiscal instruments improves overall welfare. The highest welfare gains are recorded for fiscal stimuli which lower taxes associated with wages (social contributions paid by employers and wage tax), due to their positive effect on consumption (recall the impulse response functions in Figure 2.8). On the other hand, welfare losses are found for a fiscal stimulus related to capital: government investment and capital tax. The increase in government capital crowds out consumption, and at the same time labor supply rises, which together contribute to worsening welfare (see Figure 2.7). Fiscal stimulus through a decrease in capital tax implies welfare losses, because there is a roughly neutral effect on consumption accompanied by the increase in labor supply. The ranking of all fiscal instruments, according to the consumption equivalence units, is listed in the last three columns of the table.

Regarding a ten-year fiscal stimulus, the welfare effects attain higher values than for a one-year stimulus, ranging between -0.00268 for government investment to 0.0007 for social contributions paid by employers. The ranking of fiscal instruments according to consumption equivalence units is qualitatively similar that for a one-year stimulus. Welfare losses occur with a fiscal stimulus built on government investment and capital tax. Similarly, the welfare effects of fiscal stimulus are the largest for taxes associated with wages (social contributions paid by employers and wage tax) and government consumption.

One can notice that there are some differences in the welfare effects of fiscal stimulus for optimizers and rule-of-thumb households. For instance, fiscal stimulus through social contributions paid by employers matters more for the optimizers, which reflects their ownership of monopolistic firms. Further, a decrease in capital tax improves the welfare of optimizers, pointing to the fact that optimizers own private capital in contrast to rule-of-thumb households. On the other hand, fiscal stimulus with unemployment and other social benefits bring more welfare gains for rule-of-thumb households.

Another important lesson from this analysis is that the welfare effects of fiscal stimulus differ from the output effects[20], as presented through the values of fiscal multipliers. For example, all fiscal multipliers for a one-year fiscal stimulus are positive, whereas the welfare effects of the same fiscal stimulus for some fiscal instruments are negative (namely for government investment and capital tax).

2.4.4 Fiscal Devaluation

For practical purposes, and given the lack of 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[21], this kind of shift in taxes is called a fiscal devaluation. The transmission mechanism behind the fiscal devaluation is simple. A decrease in direct taxes reflects 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 stimulate the economy (in terms of real GDP growth) by changing 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 *ex-ante* increase in consumption tax is calibrated to bring an additional 1% of GDP into the government budget. This is achieved by raising the effective tax rate on consumption by approximately 2 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 1.6 percentage points. Overall, the *ex-ante* changes in selected taxes keep the government budget neutral. The shift in these taxes is immediate and permanent. The underlying model is thus recalibrated, and a new steady state and transition matrix are computed. In this simulation, the economy converges from the old steady state to the new one. In the initial conditions, the simulation starts at the values of the old steady

[20]This finding is in line with Schwarzmüller and Wolters (2014).

[21]See for instance Koske (2013).

state, and is then governed by the transition matrix valid for the new economy (with adjusted tax rates) in the new steady state. Furthermore, for the sake of this simulation, fiscal rules for the tax rates are turned off (e.g. there are no responses of deviations of the output and debt from the new steady states to the setting of taxes over time). This simulation is depicted with blue lines in Figure 2.10 in the Appendix. The lines represent percentage deviations with respect to the old steady state.

This simulation shows that real GDP growth increases approximately by 0.5 percentage point in the first year in which the tax shift occurs from direct to indirect taxes. Nevertheless, this increase in real GDP growth is only temporary, as the economy gradually converges to the new steady state. In what follows, I elaborate on the transmission of fiscal devaluation in my model. Domestic firms face lower labor costs, and thus are more competitive in the foreign market. Additional labor is hired to cover increased demand for domestic goods. In order to hire more labor, real wages raise, which allows households to spend more of their income on consumption. Trade balance improves in the short run due to higher international competitiveness, but then worsens because of an increase in imports, which are entering into consumption goods. The improvement in real GDP growth seems to be mainly driven by improved domestic demand[22], suggesting that fiscal devaluations might be effective in more closed economies as well.

Although the exchange rate depreciates on impact, the CPI inflation slows because the effect of lower domestic producer prices dominates. Note that CPI inflation in the model does not involve changes in indirect taxation, and represents so-called monetary-policy inflation, which the central bank targets. Furthermore, it is assumed that the VAT changes are fully and immediately passed on to consumer prices. Therefore, if changes in indirect taxation are added to CPI inflation, then after-tax CPI inflation, which is relevant for the representative consumer, is initially higher in response to the VAT hike. The central bank cuts nominal interest rate in response to lower monetary-policy inflation. Having lower domestic interest rate, the uncovered interest rate parity condition induces initial depreciation of the nominal exchange rate, which later begins to appreciate. This appreciation is driven by decreased foreign debt-elastic risk premium in the UIP condition, reflecting accumulation of net foreign assets and improved trade balance.

[22] If export/import channel is muted in my model (by setting the shares of imported goods in consumption/investment/exporting goods close to zero), then fiscal devaluation continues to have a significant effect on real GDP growth, amounting to around 0.4 percentage points.

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 respective 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 percentage point, while the effective tax rate on capital grows by 1.8 percentage points. The reduction in effective tax rates on wage and social contributions paid by employers are the same as in the first simulation. The tax shift from direct taxes to consumption tax and capital tax is shown by red lines in Figure 2.10 in the Appendix. In this simulation, real GDP growth accelerates in the first year by a similar extent as in the first simulation. In this simulation, the increase in consumption tax is milder than in the first simulation, and thus private consumption accelerates faster over time. On the other hand, higher capital tax leads to a drop in private investment. As the part on investment goods is imported, this translates into the evolution of imports, which are lower than in the first simulation.

In the third simulation, fiscal devaluation happens in a fixed exchange rate regime, so as to mimic a hypothetical situation in the future after the adoption of the Euro. In this simulation the monetary policy rule (in Equation 2.61) is overridden with the following rule:

$$R_t = R_t^* prem_t, \tag{2.27}$$

meaning that the domestic interest rate is given by the setting of foreign monetary policy, adjusted for the country risk premium, which is rising with foreign indebtedness. In addition, the uncovered interest rate parity condition is replaced with:

$$S_t = S_{t-1} \exp(\varepsilon_t^{uip}), \tag{2.28}$$

to ensure that the nominal exchange rate is constant. In this equation, the ε_t^{uip} shock is interpreted as a devaluation shock to the fixed exchange rate. The results of fiscal devaluation in the context of a fixed exchange rate regime is shown in Figure 2.11. Similarly to previous simulations, there are two variants of fiscal devaluation, one relying on the consumption tax, and the second combining the adjustment in both the consumption tax and capital tax.

In the first variant of fiscal devaluation with a fixed exchange rate regime (see blue lines), the real GDP growth is boosted by 0.8 percentage points in the first year. This impact is larger than in the case of a flexible exchange rate regime, reflecting a somewhat different transmission of fiscal devaluation in the economy. Firms face lower labour costs because of decreased tax rates on wage and social contributions paid by employers, and employ additional labor and capital. Elevated real wages allow households to spend more of their income on consumption. In contrast to the flexible exchange rate, domestic monetary policy loses its power to control domestic inflationary pressures, and therefore CPI inflation rises significantly due to higher domestic demand. Since domestic prices increase, there is a surge in imported goods with unaltered prices, for use in the production of consumption and investment goods. This results in a worsening trade balance.

In the second variant of fiscal devaluation with a fixed exchange rate (light red lines in Figure 2.11), both consumption tax and capital tax are raised, and tax rates on wage and social contributions are decreased. Such a fiscal devaluation suppresses real GDP growth by approximately 0.1 percentage point in the first year. Nevertheless, there is a positive impact on real GDP in the longer horizon. The transmission mechanism differs from the first variant due to the hike in capital tax. Firms are willing to employ more labor in response to decreased tax rates on wage and social contributions, but shift away from renting capital. Both private and government investment drop. Real wages increase, and the households can afford more consumption goods at the end of the first year. Total consumption rises at a slower pace than in the first variant of fiscal devaluation with a fixed exchange rate. Since domestic demand is initially weaker and monetary policy cannot respond to such development by lowering the interest rate appropriately, CPI inflation decreases. With lower domestic prices the demand for imported goods is weakened, which manifests in an improved trade balance.

In the Czech Republic, the so-called Stabilization Reform of 2008 provides an example of a kind of fiscal devaluation, but one more focused on decreases in direct taxes. During the Reform, the reduced VAT rate was increased from 5% to 9% (resulting in an estimated +0.6 % of GDP in the government budget)[23]. Conversely, personal income tax was decreased by the introduction of a 15% flat tax rate (-0.6 % of GDP), the 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 effects of these tax shifts on the economy are depicted by golden lines in Figure 2.10 in the Appendix, with real GDP gaining 0.4 percentage point in 2008. Nonetheless, the 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

[23] *Ex-ante* estimates given in the parentheses are adopted from the Ministry of Finance.

taken into account along with tax changes, then the positive impact of fiscal devaluation on real GDP is somewhat muted, as is shown by black lines in the same figure.

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

2.5 Conclusion

I build a structural fiscal DSGE model, which is a simplified adaptation from Ambriško et al. (2015) and essentially represents an extension of the CNB's core g3 model (Andrle et al. 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 2000–2015 period.

The model is used to address several important questions. First, what is the size of fiscal multipliers in the Czech Republic? Second, what is a suitable composition of growth-friendly fiscal strategy for the Czech government based on the calculated values of fiscal multipliers? Third, what are the welfare effects of different fiscal stimuli? Forth, 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.

In addition to the output effects, I also evaluate welfare effects of different fiscal stimuli. The highest welfare gains for the households are found for fiscal stimuli which lower taxes associated with wages (social contributions paid by employers and wage tax) or increase government consumption.

Given the lack of 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 0.5 percentage points in the first year in which a budget-neutral tax shift in magnitude of 1% of GDP occurs from direct taxes associated with wages to consumption tax. Real GDP gain becomes even larger, amounting 0.8 percentage points in the first year, if fiscal devaluation happens in a hypothetical case of fixed exchange rate regime. Furthermore, to illustrate using a real world example, the model is used to evaluate past fiscal devaluation, which occurred in the Czech Republic's 2008 Stabilization Reform.

Several directions are possible for related future research. 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.

Appendix

2.A The Rest of the Model

2.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.

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:

$$Y_t(z) = \varsigma_t \left(A_t L_t(z)\right)^{1-\alpha} K_{t-1}(z)^{\alpha}, \tag{2.29}$$

in which ς_t and A_t are the total factor productivity shock and labor-augmenting technology process, and labor input is defined as $L_t(z) = (\int_0^1 [L_t(z,i)]^{\frac{\epsilon_W - 1}{\epsilon_W}} di)^{\frac{\epsilon_W}{\epsilon_W - 1}}$, in which 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:

$$L_t(z,i) = \left[\frac{W_t(i)}{W_t}\right]^{-\epsilon_W} L_t(z), \tag{2.30}$$

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

$$\int_0^1 Y_t(z) dz = \varsigma_t \left(A_t L_t\right)^{1-\alpha} {K_{t-1}}^{\alpha} \tag{2.31}$$

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 (2.29). 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:

$$\frac{P_t^K}{P_t^Y} = RMCY_t \alpha \frac{Y_t}{K_{t-1}} \left(\frac{\alpha_K K_{t-1}}{K_{t-1}^p}\right)^{\frac{1}{v_K}} \tag{2.32}$$

$$(1+\tau_t^S)\frac{W_t}{P_t^Y} = RMCY_t(1-\alpha)\frac{Y_t}{L_t}, \tag{2.33}$$

in which 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:

$$\log\frac{\Pi_t^Y}{\Pi_{t-1}^Y} = \beta\log\frac{\Pi_{t+1}^Y}{\Pi_t^Y} + \frac{(1-\xi_Y)(1-\beta\xi_Y)}{\xi_Y}\log(RMCY_t\Theta^Y) + \varepsilon_t^Y, \tag{2.34}$$

in which 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:

$$Y_t = Y_t^C + Y_t^I + Y_t^G + Y_t^X \tag{2.35}$$

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:

$$N_t(z^N) = a_t^N\left[\int_0^1 [o_t(f)]^{\frac{\theta-1}{\theta}}\,df\right]^{\frac{\theta}{\theta-1}}, \tag{2.36}$$

in which 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:

$$\int_0^1 N_t(z^N)dz^N = N_t^C + N_t^I + N_t^X \tag{2.37}$$

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

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:

$$\int_0^1 C_t^p(z^C)dz^C = \left[(\omega_C)^{\frac{1}{\eta_C}}\left(N_t^C\right)^{\frac{\eta_C-1}{\eta_C}} + (1-\omega_C)^{\frac{1}{\eta_C}}\left(Y_t^C\right)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}}, \tag{2.38}$$

in which 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.

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:

$$\int_0^1 I_t(z^I)dz^I = a_t^I\left[(\omega_I)^{\frac{1}{\eta_I}}\left(N_t^I\right)^{\frac{\eta_I-1}{\eta_I}} + (1-\omega_I)^{\frac{1}{\eta_I}}\left(Y_t^I\right)^{\frac{\eta_I-1}{\eta_I}}\right]^{\frac{\eta_I}{\eta_I-1}}, \tag{2.39}$$

in which 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.

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:

$$\int_0^1 X_t(z^X)dz^X = \left[(\omega_X)^{\frac{1}{\eta_X}}\left(N_t^X\right)^{\frac{\eta_X-1}{\eta_X}} + (1-\omega_X)^{\frac{1}{\eta_X}}\left(Y_t^X\right)^{\frac{\eta_X-1}{\eta_X}}\right]^{\frac{\eta_X}{\eta_X-1}}, \tag{2.40}$$

in which 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:

$$\log\frac{\widetilde{\Pi}_t^X}{\widetilde{\Pi}_{t-1}^X} = \beta\log\frac{\widetilde{\Pi}_{t+1}^X}{\widetilde{\Pi}_t^X} + \frac{(1-\xi_X)(1-\beta\xi_X)}{\xi_X}\log\left(RMCX_t\Theta^X\right) + \varepsilon_t^X, \tag{2.41}$$

in which $\xi_X > 0$ 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:

$$X_t = \left(\frac{P_t^X}{P_t^*}\right)^{-\theta_X} N_t^*, \tag{2.42}$$

in which $\theta_X > 0$ 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).

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:

$$\int_0^1 G_t(z^G)dz^G = a_t^G Y_t^G, \tag{2.43}$$

in which 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.

2.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, and thus in 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 along with the assumption of the 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:

$$\max_{W_t^*(i)} E_t \sum_{s=0}^{\infty} (\beta\xi_W)^{t+s} \left\{ \begin{array}{c} (1-\gamma)\left[\lambda_{t+s}^{co}(i)(1-\tau_{t+s}^{WUB})W_t^*(i)\frac{W_{t+s-1}}{W_{t-1}}L_{t+s}^o(i)\right] \\ +\gamma\left[\lambda_{t+s}^{cr}(i)(1-\tau_{t+s}^{WUB})W_t^*(i)\frac{W_{t+s-1}}{W_{t-1}}L_{t+s}^r(i)\right] \\ -\left[(1-\gamma)\theta\frac{\left(L_{t+s}^o(i)\right)^{1+\phi_n}}{1+\phi_n} + \gamma\theta\frac{\left(L_{t+s}^r(i)\right)^{1+\phi_n}}{1+\phi_n}\right] \end{array} \right\} \quad (2.44)$$

subject to the labor demand condition:

$$L_t(i) = \left[\frac{W_t(i)}{W_t}\right]^{-\epsilon^W} L_t, \quad (2.45)$$

in which 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 types 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:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_W)^{t+s} \frac{L_{t+s}^o(i)^{1+\phi_n}}{W_t^*(i)} \left[\begin{array}{c} \left(\frac{1-\gamma}{MRS_{t+s}^o(i)} + \frac{\gamma}{MRS_{t+s}^r(i)}\right) * \\ *(1-\tau_{t+s}^{WUB})W_t^*(i)\frac{W_{t+s-1}}{W_{t-1}} - \Theta^W \end{array} \right] = 0, \quad (2.46)$$

in which $\Theta^W = \frac{\epsilon^W}{\epsilon^W - 1}$ is the desired (flexible) wage markup and $MRS_t^o(i)$, $MRS_t^r(i)$ 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 2.A.1), one can obtain the following wage Phillips curve:

$$\log \frac{\Pi_t^W}{\Pi_{t-1}^W} = \beta \log \frac{\Pi_{t+1}^W}{\Pi_t^W} - \frac{(1-\xi_W)(1-\beta\xi_W)}{\xi_W(1+\epsilon^W\phi_n)} \log \frac{\Theta_t^W}{\Theta^W} + \varepsilon_t^W, \tag{2.47}$$

in which $\Theta_t^W = \frac{(1-\tau_t^{WUB})W_t}{P_t MRS_t}$ 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_t^W 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:

$$MRS_t^k(i) = -\frac{U_{n(i),t}^k}{U_{c,t}^k} = \frac{\theta\left[L_t^k(i)\right]^{\phi_n}}{\lambda_t^{ck}}, \tag{2.48}$$

in which λ_t^{ck} 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:

$$mrs_t = \log\theta + \phi_n l_t - \tilde{\lambda}_t^c, \tag{2.49}$$

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

Unemployment

The unemployment introduced into this model uses the framework of Galí (2011), in which 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:

$$\frac{(1-\tau_t^{WUB})W_t(i)}{P_t^C} \geq \frac{\theta j^{\phi_n}}{\lambda_t^c} \tag{2.50}$$

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:

$$\frac{(1-\tau_t^{WUB})W_t(i)}{P_t^C} = \frac{\theta\left[L_t^P(i)\right]^{\phi_n}}{\lambda_t^{ck}} \tag{2.51}$$

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

$$\log(1-\tau_t^{WUB}) + w_t - p_t^c = \log\theta + \phi_n l_t^P - \tilde{\lambda}_t^c, \tag{2.52}$$

in which $w_t = \int_0^1 w_t(i)di$ 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:

$$u_t = l_t^P - l_t \tag{2.53}$$

Combining equations (2.49) and (2.52) with the expression for the average wage markup, the following simple relationship between the wage markup and the unemployment rate arises:

$$\log\Theta_t^W = \phi_n u_t \tag{2.54}$$

This expression can be substituted back into the wage Phillips curve (2.47), 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:

$$u^n = \frac{\log\Theta^W}{\phi_n} \tag{2.55}$$

2.A.3 Foreign Block

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

$$S_t R_t = (E_t S_{t+1})^{\rho_s} (S_{t-1})^{1-\rho_s} R_t^* prem_t \exp(\varepsilon_t^{uip}) \tag{2.56}$$

$$prem_t = (prem_{t-1})^{\rho_p} \exp(-\zeta_B B_t^* + \varepsilon_t^{prem}), \tag{2.57}$$

in which 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:

$$TB_t = P_t^X X_t - P_t^* N_t, \tag{2.58}$$

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

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

$$B_t^* = \frac{S_t}{S_{t-1}} B_{t-1}^* R_{t-1}^* + TB_t \tag{2.59}$$

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:

$$\begin{aligned}
\widetilde{\Pi}_t^* &= \left(\widetilde{\Pi}_{t-1}^*\right)^{\rho_{ps}} \exp(\varepsilon_t^{ps}) \\
\frac{R_t^*}{\bar{R}} &= \left(\frac{R_{t-1}^*}{\bar{R}}\right)^{\rho_{rs}} \exp(\varepsilon_t^{rs}) \\
\frac{N_t^*}{\bar{N}^*} &= \left(\frac{N_{t-1}^*}{\bar{N}^*}\right)^{\rho_{ns}} \exp(\varepsilon_t^{ns}),
\end{aligned} \tag{2.60}$$

in which $\widetilde{\Pi}_t^* = \widetilde{P}_t^* / \widetilde{P}_{t-1}^*$, 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.

2.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:

$$R_t = (R_{t-1})^{\rho_i} \left[\bar{R} \left(\frac{\Pi^{C4}_{t+4}}{\overline{\Pi}} \right)^{\phi_\pi} \right]^{1-\rho_i} \exp(\varepsilon^M_t), \tag{2.61}$$

in which $\bar{R}$ is the steady state nominal gross interest rate, $\Pi^{C4}_t = P^C_t / P^C_{t-4}$ 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^M_t is a normally distributed monetary policy shock. The central bank targets the year-on-year deviation of CPI inflation, excluding changes in indirect taxation, from its target four periods ahead. The exclusion of changes in indirect taxation is particularly relevant for fiscal devaluation, since the central bank does not raise interest rates in response to higher tax rate on consumption.

2.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:

$$\begin{aligned} C_t &= \gamma C^r_t + (1-\gamma) C^o_t \\ C^p_t &= \gamma C^{pr}_t + (1-\gamma) C^{po}_t \\ G_t &= \gamma G^r_t + (1-\gamma) G^o_t \\ OB_t &= \gamma OB^r_t + (1-\gamma) OB^o_t \\ T_t &= \gamma T^r_t + (1-\gamma) T^o_t \\ L_t &= \gamma L^r_t + (1-\gamma) L^o_t, \end{aligned} \tag{2.62}$$

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

$$\begin{aligned} B_t &= (1-\gamma) B^o_t \\ K^p_t &= (1-\gamma) K^{po}_t \\ I^p_t &= (1-\gamma) I^{po}_t \end{aligned} \tag{2.63}$$

$$D_t = (1-\gamma)D_t^o$$

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

$$GDP_t = P_t^C C_t^p + P_t^I I_t + P_t^G G_t + P_t^X X_t - P_t^* N_t \tag{2.64}$$

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

$$\begin{aligned} \frac{RGDP_t}{RGDP_{t-1}} &= \frac{P_{t-1}^C C_{t-1}^p}{GDP_{t-1}} \frac{C_t^p}{C_{t-1}^p} + \frac{P_{t-1}^I I_{t-1}}{GDP_{t-1}} \frac{I_t}{I_{t-1}} + \frac{P_{t-1}^G G_{t-1}}{GDP_{t-1}} \frac{G_t}{G_{t-1}} + \\ &+ \frac{P_{t-1}^X X_{t-1}}{GDP_{t-1}} \frac{X_t}{X_{t-1}} - \frac{P_{t-1}^* N_{t-1}}{GDP_{t-1}} \frac{N_t}{N_{t-1}} \end{aligned} \tag{2.65}$$

2.B Tables and Figures

Table 2.1: 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 2.1 – 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 2.2: Effective Tax Rates (in %)

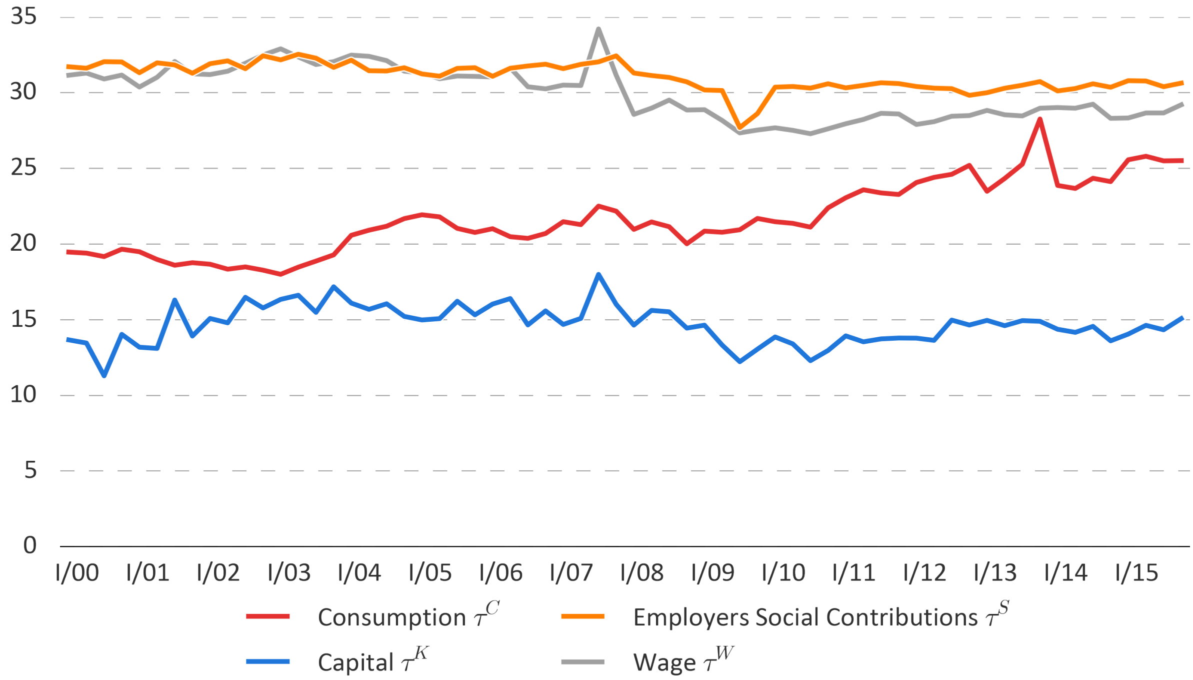


Table 2.2: Input Data

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 2.3: Priors and Posteriors of Estimated Parameters

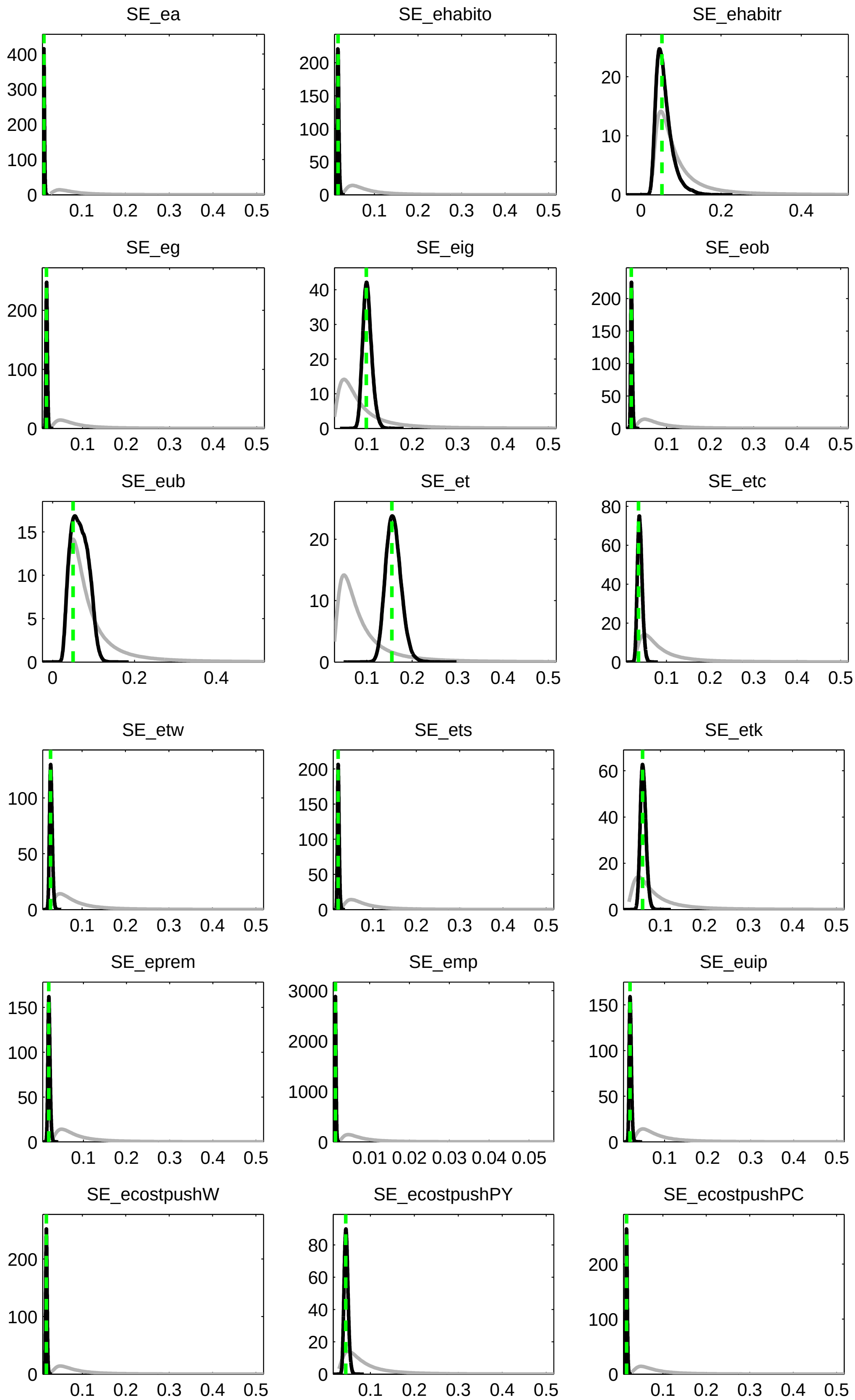


Figure 2.4: Priors and Posteriors of Estimated Parameters (Continued)

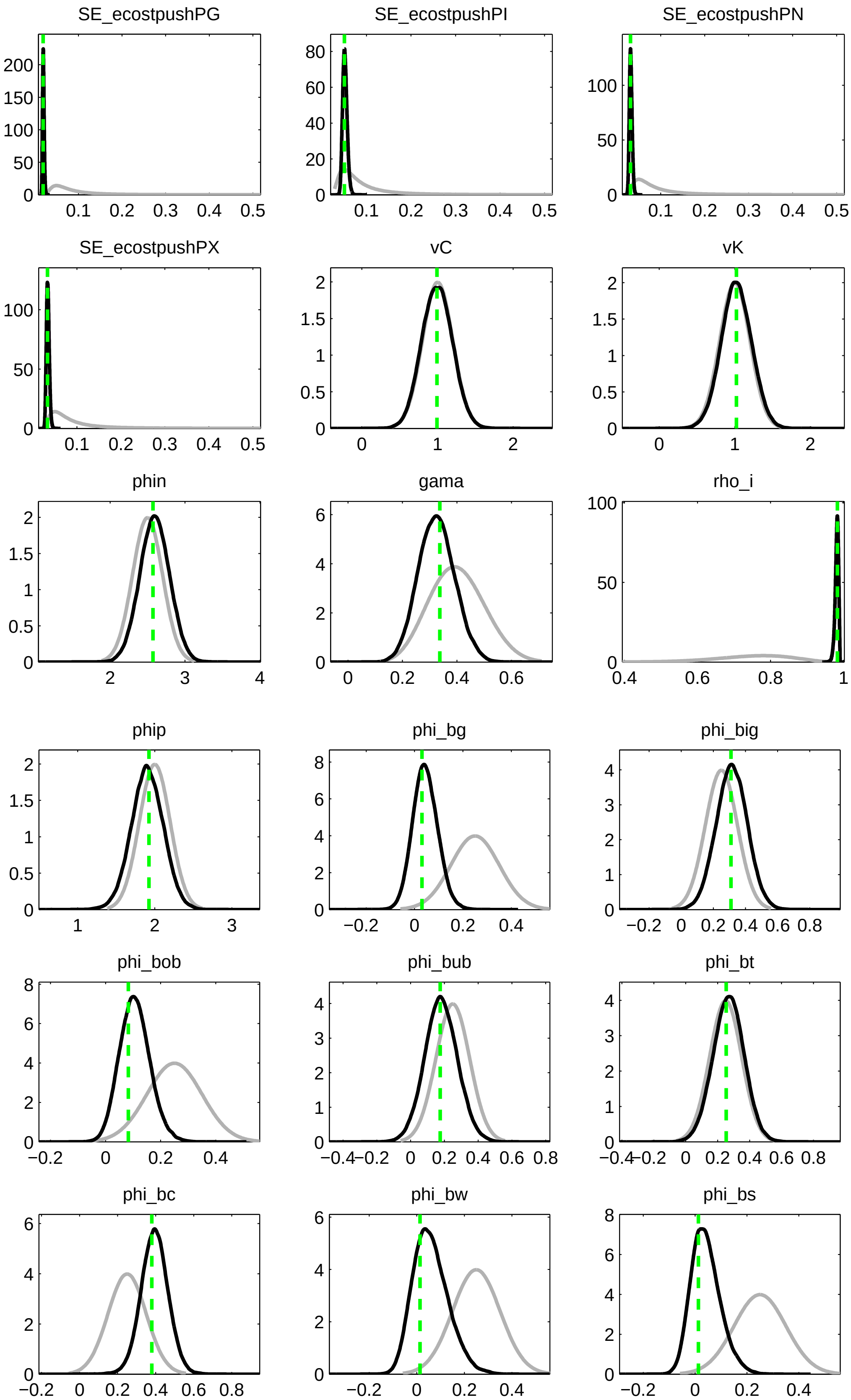


Figure 2.5: Priors and Posteriors of Estimated Parameters (Continued)

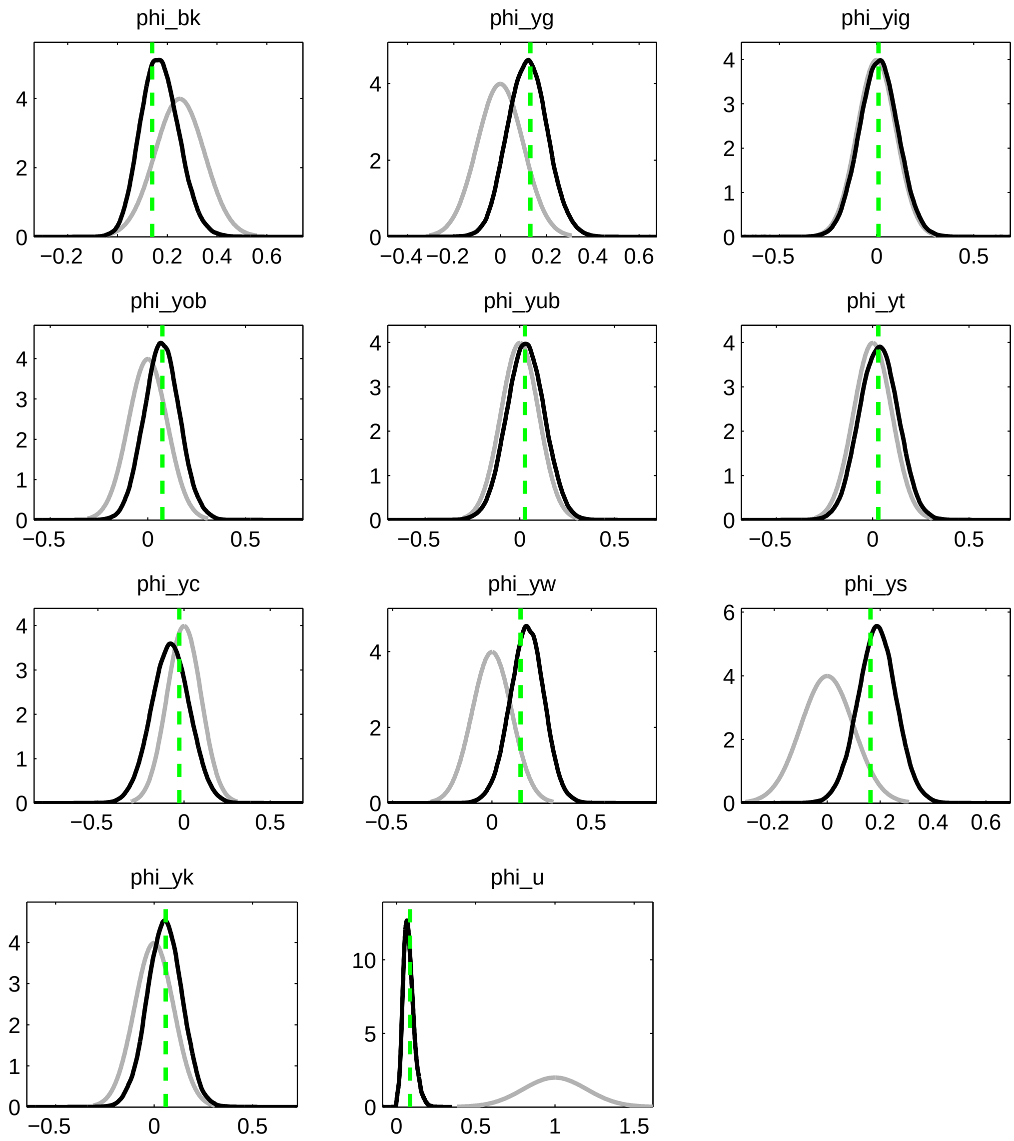


Figure 2.6: Multivariate Convergence Diagnostics

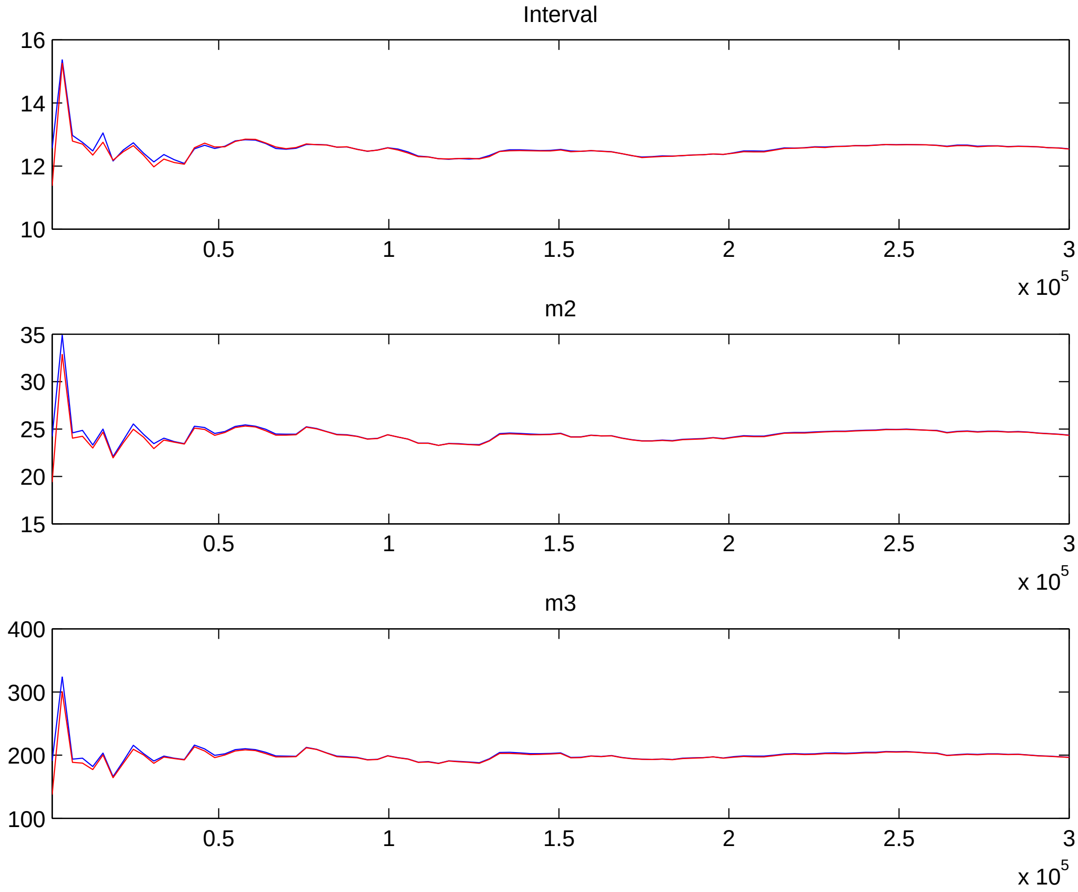


Table 2.3: Estimated Parameters

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 2.3 – 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 2.4: 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. Fiscal rules are turned off for the initial two years.

Table 2.5: Real GDP Fiscal Multipliers with Active Fiscal Rule

	Years				Peak	LR
	1	2	5	10		
One-year stimulus						
Expenditures (+):						
Government consumption	0.47	0.31	0.24	0.26	0.59	0.38
Government investment	0.32	0.18	0.26	0.26	0.42	0.16
Unemployment benefits	0.13	0.09	0.26	0.22	0.26	0.25
Other social benefits	0.05	-0.11	-0.15	-0.15	0.17	-0.11
Taxes (-):						
Consumption tax	0.17	0.06	0.05	0.02	0.23	-0.02
Wage tax	0.14	0.11	0.30	0.25	0.30	0.28
Social contributions employers	0.17	0.24	0.08	0.20	0.29	0.29
Capital tax	-0.14	-0.25	-0.19	-0.19	-0.05	-0.11
Lump-sum tax	0.05	-0.11	-0.13	-0.14	0.18	-0.11
10-year stimulus						
Expenditures (+):						
Government consumption	0.47	0.35	0.27	0.26	0.59	0.34
Government investment	0.32	0.24	0.24	0.25	0.42	0.13
Unemployment benefits	0.13	0.11	0.19	0.21	0.24	0.24
Other social benefits	0.05	-0.06	-0.12	-0.14	0.17	-0.11
Taxes (-):						
Consumption tax	0.17	0.10	0.07	0.05	0.23	-0.01
Wage tax	0.14	0.12	0.22	0.24	0.28	0.28
Social contributions employers	0.17	0.22	0.13	0.16	0.29	0.29
Capital tax	-0.14	-0.21	-0.21	-0.20	-0.05	-0.11
Lump-sum tax	0.05	-0.05	-0.11	-0.13	0.18	-0.10

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. Fiscal rules are active in the economy for whole simulation period.

Figure 2.7: Impulse Response Functions for Government Expenditure

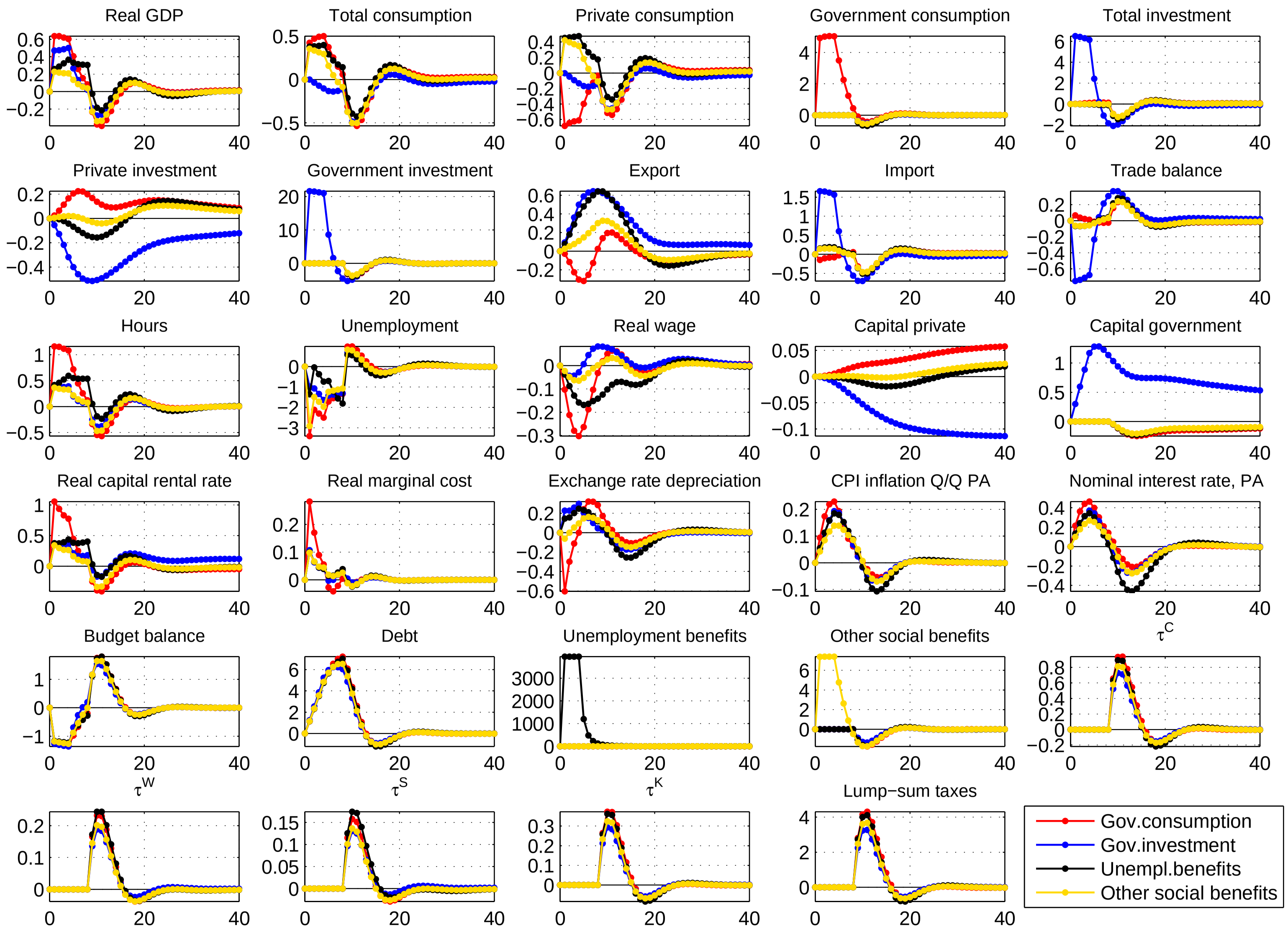


Figure 2.8: Impulse Response Functions for Taxes

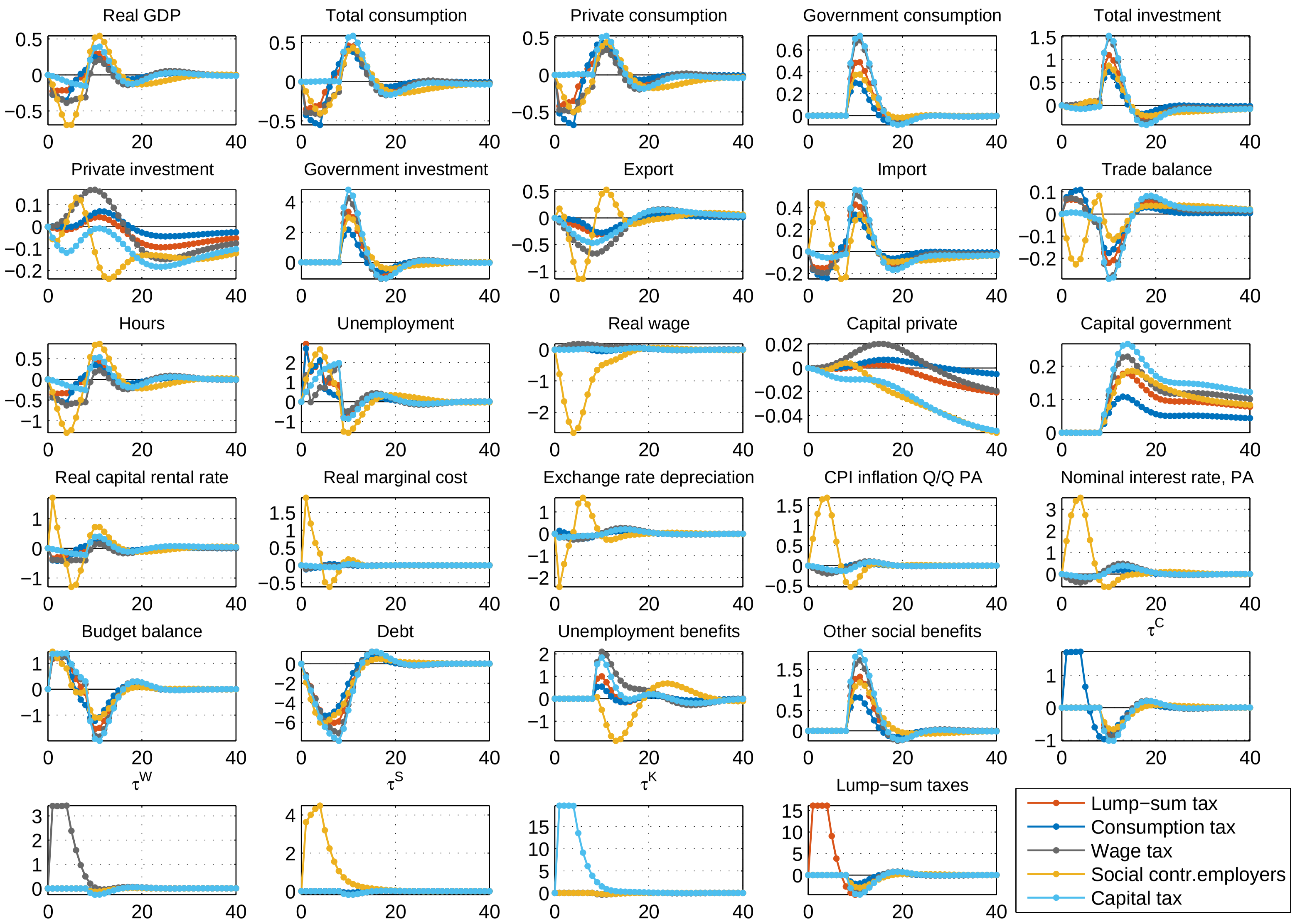


Figure 2.9: Impulse Response Functions for Capital Tax

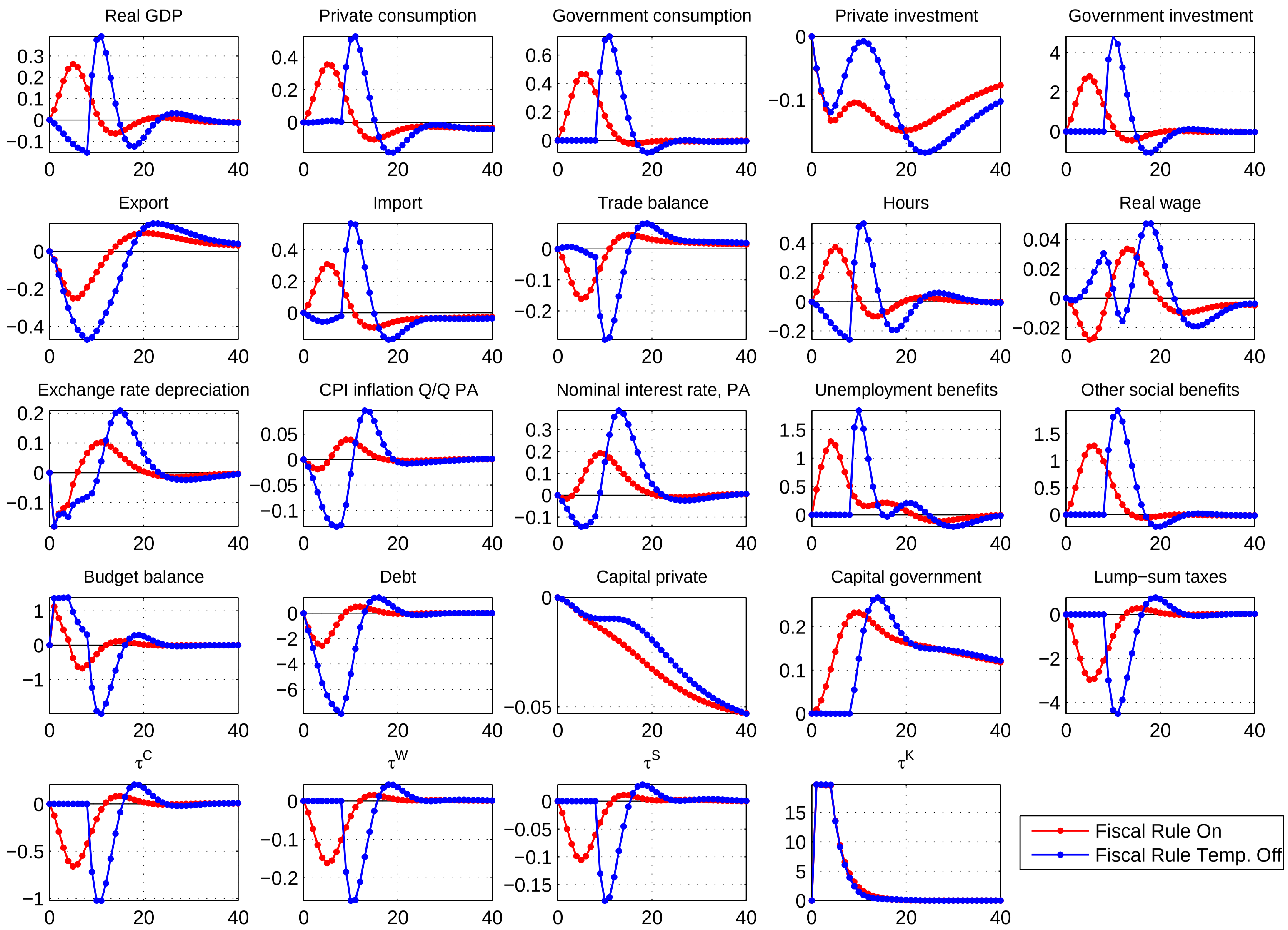


Table 2.6: Fiscal Scores for Consolidation

	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 2.7: 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 2.8: 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 2.9: 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%.

Table 2.10: Welfare Effects of Fiscal Instruments

	Cons.equivalence units			Ranking		
	λ	λ^o	λ^r	λ	λ^o	λ^r
One-year stimulus						
Expenditures (+):						
Government consumption	0.00009	0.00012	0.00004	3	3	5
Government investment	-0.00027	-0.00023	-0.00035	9	9	9
Unemployment benefits	0.00009	0.00007	0.00012	4	5	2
Other social benefits	0.00002	-0.00001	0.00009	7	8	4
Taxes (-):						
Consumption tax	0.00004	0.00003	0.00004	5	6	6
Wage tax	0.00011	0.00008	0.00016	2	4	1
Social contributions employers	0.00013	0.00018	0.00002	1	1	7
Capital tax	-0.00003	0.00012	-0.00034	8	2	8
Lump-sum tax	0.00003	0.00000	0.00010	6	7	3
10-year stimulus						
Expenditures (+):						
Government consumption	0.00063	0.00079	0.00028	2	2	6
Government investment	-0.00268	-0.00228	-0.00353	9	9	9
Unemployment benefits	0.00051	0.00039	0.00076	5	6	4
Other social benefits	0.00021	-0.00010	0.00087	7	8	3
Taxes (-):						
Consumption tax	0.00057	0.00064	0.00041	4	4	5
Wage tax	0.00061	0.00047	0.00088	3	5	2
Social contributions employers	0.00070	0.00103	0.00003	1	1	7
Capital tax	-0.00023	0.00073	-0.00225	8	3	8
Lump-sum tax	0.00023	-0.00009	0.00090	6	7	1

Note: λ, λ^o and λ^r represent welfare effects of fiscal stimulus, expressed in consumption equivalence units for aggregate, optimizer and rule-of-thumb households. Positive values indicate welfare gains, whereas negative values indicate welfare losses. 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. Fiscal rules are turned off for the initial two years.

Figure 2.10: The Simulations of Fiscal Devaluations

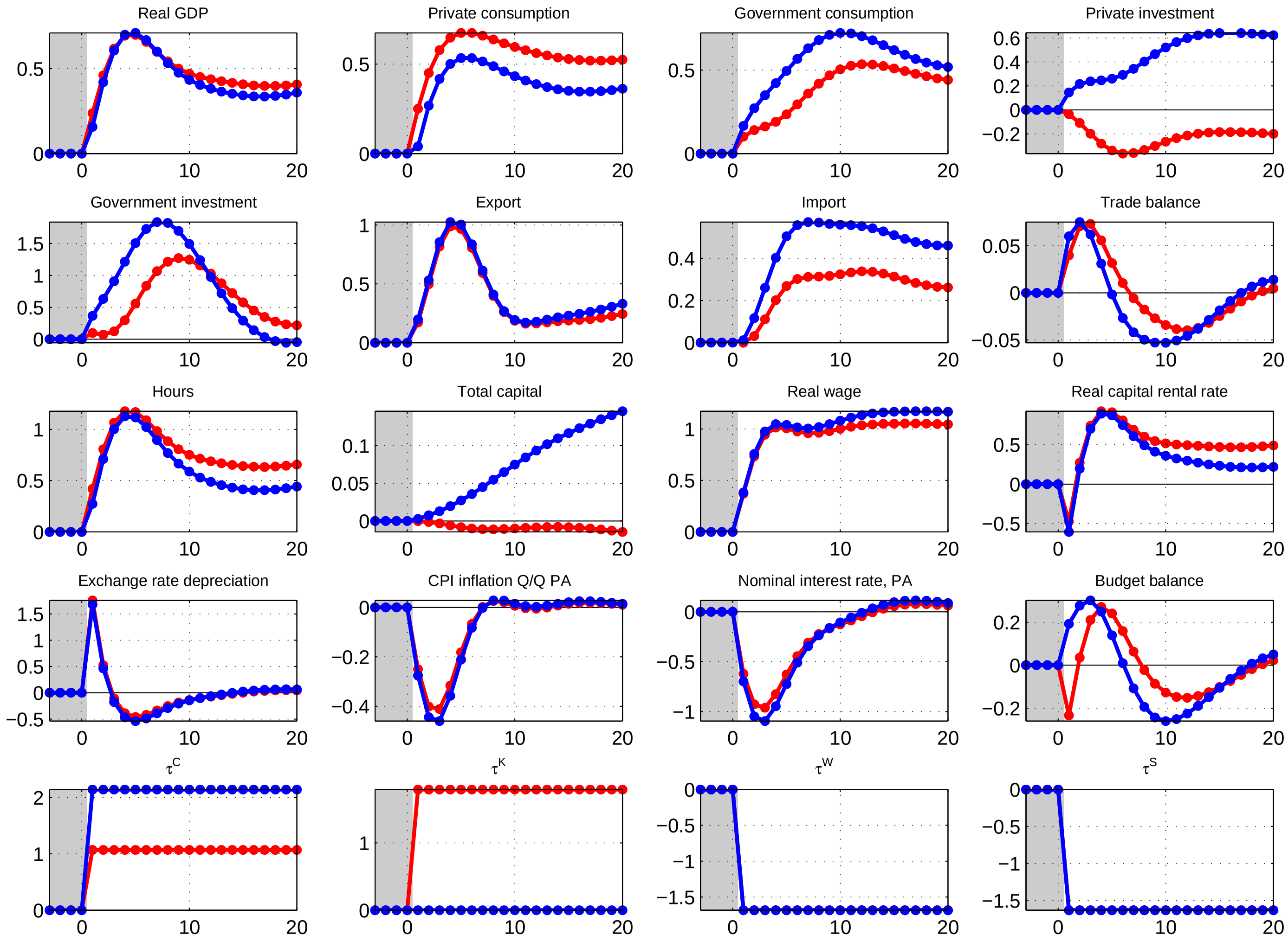


Figure 2.11: The Simulations of Fiscal Devaluations with a Fixed Exchange Rate Regime

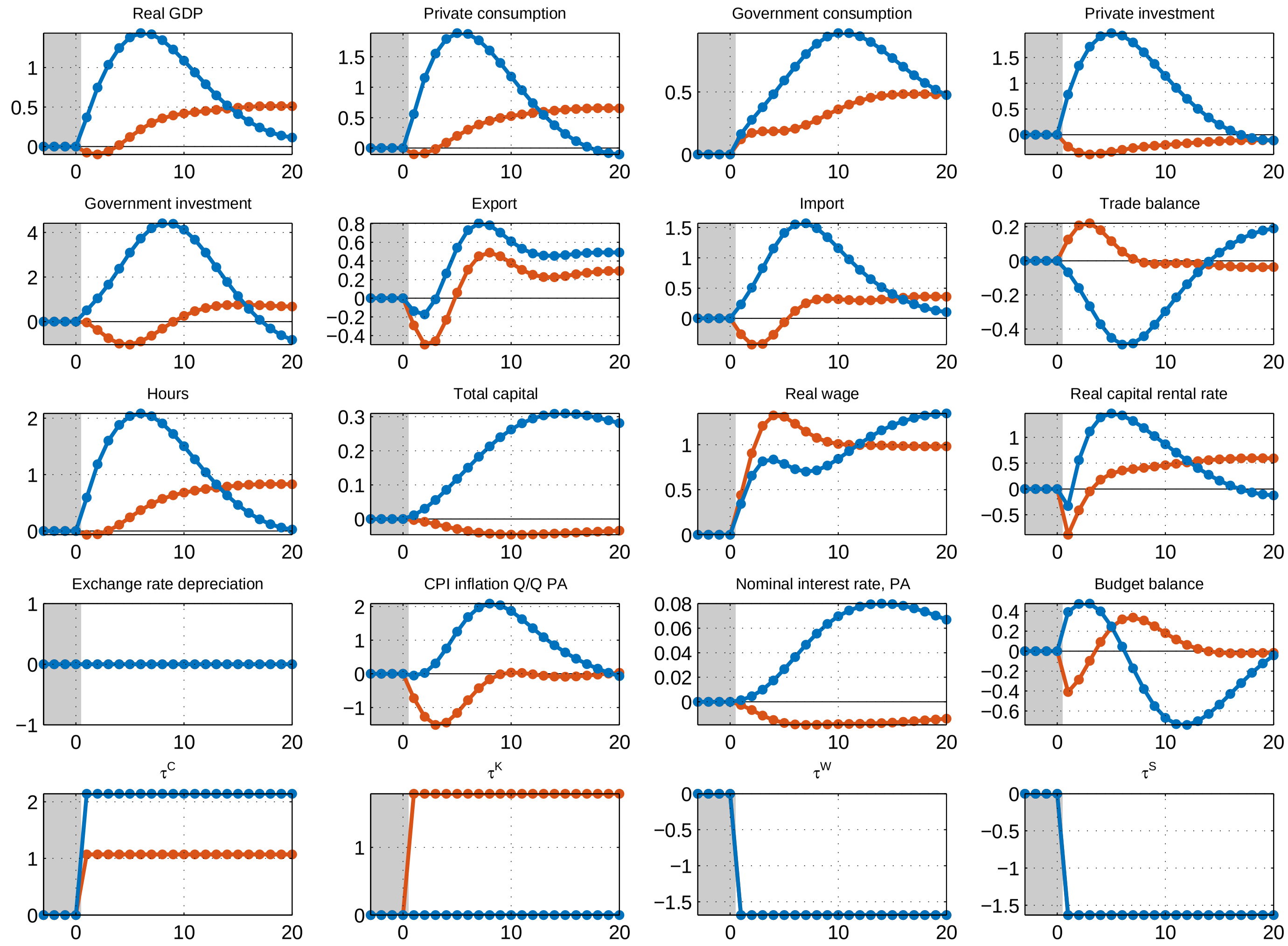
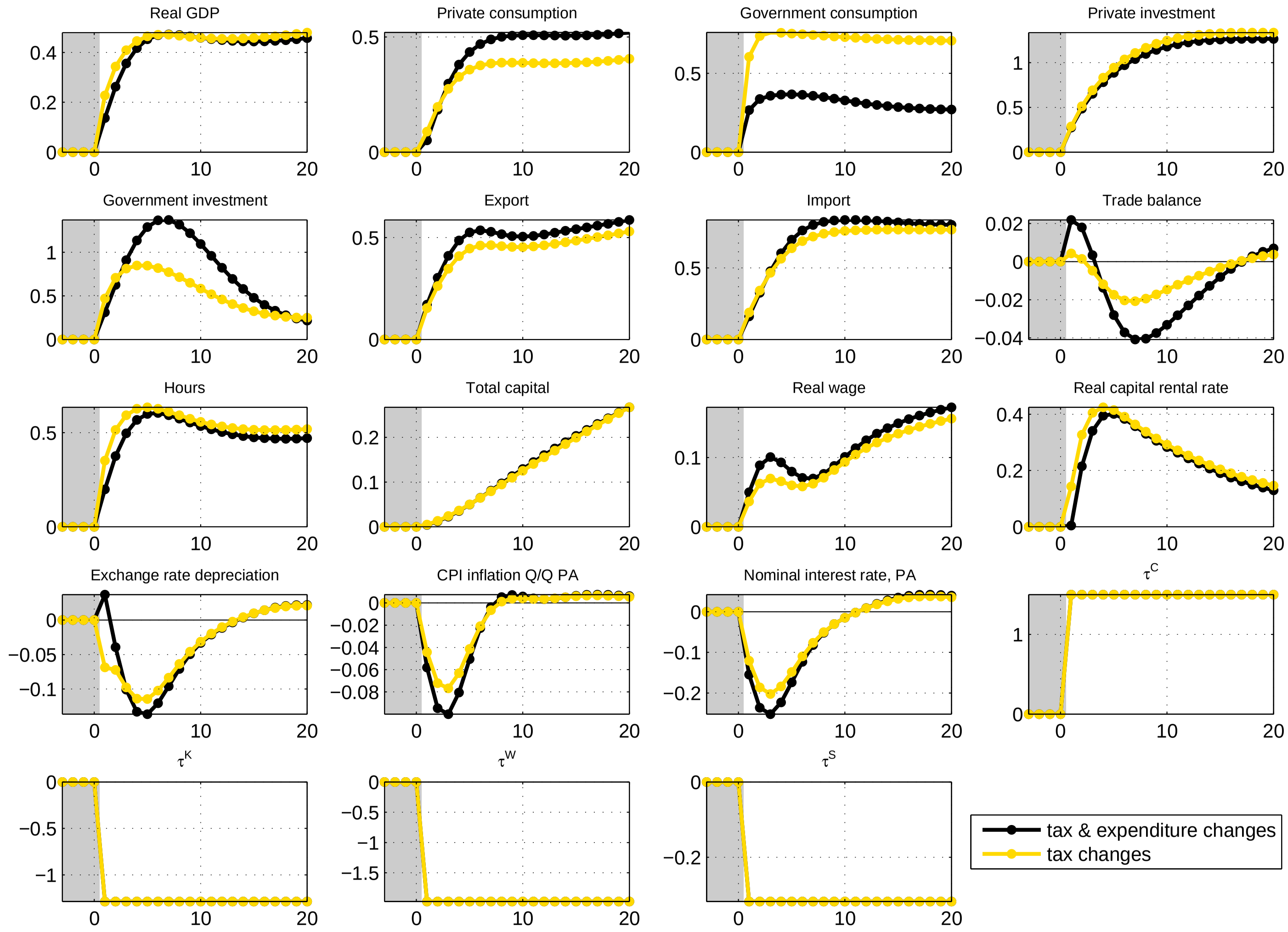


Figure 2.12: Fiscal Devaluation in the 2008 Stabilisation Reform



Chapter 3

Fiscal Discretion in the Czech Republic[1]

3.1 Introduction

Fiscal discretion is a powerful tool in the hands of the government, which is used frequently to influence the economy. Fiscal discretion can be understood as changes in taxes and government spending aimed at influencing macroeconomic developments (e.g. the lowering of payroll taxes, a hike in the value added tax rate, the introduction of higher indexation of pensions). Importantly, these changes are other than those induced by the business cycle.

In this chapter, I address several important research questions related to fiscal discretion. First, what were the impacts of fiscal discretion on the Czech economy in the past? Second, has fiscal discretion helped to stabilize the economy? Third, how large is the real GDP loss due to an ineffective composition of fiscal discretion? I elaborate on each of these questions and corresponding answers in the following paragraphs.

Fiscal discretion is identified by two approaches: bottom-up and top-down. The bottom-up approach is essentially a collection of past discretionary fiscal measures and their budgetary impacts, taken from various government documents. The top-down approach, represented by changes in the structural government budget balance, is used as an alternative approach to cross-check the results of the bottom-up approach. Having

[1] This chapter is an updated and extended version on my previous joint work with the colleagues from the Czech National Bank Ambriško et al. (2012): "Fiscal Discretion in the Czech Republic in 2001-2011: Has It Been Stabilizing?" Czech National Bank Research and Policy Note No. 1/2012. I elaborate on my specific extensions in Section 3.2.

identified fiscal discretion, one can estimate the impact of fiscal discretion on the economy by using fiscal multipliers. The size of fiscal discretion of a selected revenue or expenditure category, as identified by the bottom-up approach and expressed as a percentage of GDP, is multiplied by the fiscal multiplier valid for the respective fiscal category. For this calculation, I utilize my own set of fiscal multipliers for several categories of tax revenues and government expenditures, as available in Ambriško (2016) or in the previous chapter 2.4.1. For robustness, I employ an additional DSGE method to estimate the impact of fiscal discretion on the economy. The DSGE model with fiscal sector, developed in Chapter 2, is utilized to retrieve the contributions of fiscal discretion to real GDP growth in the past. Overall, I find that fiscal discretion in the Czech Republic was used frequently, and some sizeable impacts on real GDP growth were recorded, particularly in years 2004, 2009 and 2016, with estimated impacts reaching about 1.0–1.5 p.p. in real GDP growth[2].

Another important question is whether fiscal discretion mutes or amplifies the business cycle. Do fiscal austerities happen in positive economic conditions or not? Do fiscal expansions occur in negative economic conditions or not? In other words, is fiscal discretion pro-cyclical, counter-cyclical, or rather a-cyclical? To answer these questions, I compare the impacts of fiscal discretion on real GDP growth against the output gap, investigating whether or not those two tends move together in the same direction. I find with the bottom-up approach that fiscal discretion in the Czech Republic was pro-cyclical in the years 2008, 2010, 2012–2013, and 2016–2017, whereas it was counter-cyclical in 2009, 2011, and 2014–2015. No obvious link between fiscal discretion and the output gap can be distinguished, suggesting that, on average, Czech fiscal discretion has not contributed to stabilizing business cycle fluctuations.

Further, the composition of fiscal discretion is what matters for the economy. In the past, the government might have placed excessive emphasis on fiscal instruments that are detrimental to real GDP growth, rather than certain other hypothetical, more growth-friendly structure of fiscal instruments. Had past fiscal discretion in the Czech Republic had a better growth-friendly composition, as suggested by Ambriško (2016) and computed in the previous chapter, then real GDP could have grown faster. With a desirable composition of fiscal discretion, the estimated cumulative gain in real GDP growth amounts to approximately 1.8 p.p. over the 2001–2017 period. This result can be also translated into an average annual loss of 0.15 p.p. of real GDP growth due to the

[2]These impacts come from the bottom-up approach; the impacts from the DSGE approach are presented in Chapter 3.4.3.

ineffective composition of fiscal discretion.

It is important to note that I focus on the stabilization function of fiscal policy, because I estimate the impacts of fiscal discretion only on real GDP. There are other relevant functions of fiscal policy to be considered, including redistributing income and allocating public goods, as already advocated by Musgrave (1953). These additional functions of fiscal policy are neglected in my analysis. However, they provide a good idea for further research, which would encompass wider functions of fiscal policy for the analysis of fiscal discretion.

This chapter is organized as follows. Section 2 reviews relevant literature, and Section 3 describes the methodology used for the derivation of fiscal discretion. Section 4 analyzes the economic impacts of fiscal discretion, cyclicality of fiscal policy, and the composition of fiscal discretion. The last section summarizes the main findings and suggests several ideas for possible future research.

3.2 Review of Relevant Literature

Fiscal discretion in the Czech Republic is analyzed in detail in Ambriško et al. (2012), in which the authors quantify the impacts of Czech fiscal policy on real GDP in the 2001–2011 period and find little evidence of counter-cyclical fiscal policy in the Czech Republic. My paper extends this previous work by adding the following features. First, I use data that covers a larger time span; up to the more recent year of 2017. Second, the analysis of fiscal discretion in this paper goes into more detail; specifically, it is more disaggregated into individual tax revenue and government expenditure categories. Third, the impacts of fiscal discretion on real GDP growth are retrieved from the DSGE model with fiscal sector. Forth, I compare the effects of the past composition of fiscal discretion on real GDP with a hypothetical, more growth-friendly composition of fiscal discretion, which is a novel contribution in the field of Czech fiscal policy.

The bottom-up approach used in my analysis for collecting fiscal measures resembles the narrative approach found in the VAR literature, developed by Romer and Romer (2010), and further applied, for instance, by Cloyne (2013). Both approaches determine the size and timing of fiscal changes in the historical records. The narrative approach focuses specifically on tax changes and divides them into exogenous changes (affecting/raising the normal growth of the economy) and endogenous changes (taken to offset deviations of output growth from normal). This classification of changes is deemed important to making unbiased estimates for the impact of tax changes on GDP. For US data Romer and Romer (2010) found that a tax increase of 1 percent of GDP decreases real GDP by almost three percent over three years. On the other hand, the bottom-up approach employed in my analysis does not classify which measures have an exogenous or endogenous nature. For the Czech Republic, historical records of fiscal measures do not seem to be long enough to pursue a fully-fledged narrative approach. Another important difference is that this chapter does not aim to estimate the degree to which fiscal discretion affects real GDP, but to quantify the contributions of fiscal discretion on real GDP, utilizing fiscal multipliers and filtration in the DSGE model.

In identifying fiscal discretion by the top-down method (meaning that aggregated data are used, namely the government budget balance), one needs to calculate the structural government budget balance from the total government budget balance, e.g. by removing one-off measures and an estimated (unobserved) cyclical component from the government budget balance. There are several methods to calculate cyclically-adjusted budget balances. The most notable were devised by the European Central Bank (as described in Bouthevillain et al. (2001) and labelled as the ESCB method of cyclical adjustment) and European Commission (Mourre, Astarita, and Princen 2014). The adjusted variants of the European Commission method are employed by the IMF and the OECD (van den Noord 2000). Lang and Mareš (2015) provide a good comparison of the methods of cyclical adjustment of the government balance in the Czech Republic context.

Concerning the Czech Republic, there is growing literature on fiscal multipliers. A fiscal multiplier of 0.6 is estimated in Hřebíček, Král, and Říkovský (2005) using both regression analysis and structural simulation. Prušvic (2010) ascertains 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), in which the authors calibrate the IMF's GIMF model for the Czech Republic and find the highest multipliers for government consumption and investment, both reaching 0.4. In a similar manner, the OECD (2009), utilising its INTERLINK macroeconometric model, lists the highest multipliers for government investment (0.7) and government consumption (0.3). Using the SVAR model, Valenta (2011) estimates the fiscal multiplier for government spending in the range of 0.3-0.6. Fiscal multipliers from an estimated DSGE model are available in Ambriško (2016), with the highest fiscal multipliers associated with government consumption (0.6), government investment (0.5), and social security contributions paid by employers (0.4). This set of fiscal multipliers is used in the following analysis to calculate the impact of fiscal discretion on real GDP growth. Selected fiscal multipliers, relevant for the Czech Republic, are listed in Table 3.1 in the Appendix.

So far, the literature on the suitable composition of fiscal discretion is relatively sparse. Growth-friendly fiscal strategies for the Czech Republic are derived in Ambriško (2016) according to the simplified methodology of the European Central Bank (ECB) (Drudi et al. 2015). This methodology provides a ranking of the fiscal instruments according to their usefulness to the real economy, e.g., giving higher priority to fiscal instruments that are the least harmful to real GDP during fiscal consolidation and to those that are the most beneficial to boosting real GDP during fiscal stimulus. Alternatively, a 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.

3.3 Methodology

Fiscal discretion is identified by several methods, namely the bottom-up approach and the top-down approach. I focus mainly on the bottom-up approach, in which one collects individual measures on the revenue and expenditure side of the government budget. The top-down approach, which works with aggregated government data (government budget balance), is used to cross-check the consistency of the fiscal discretion that is derived by the bottom-up approach. In addition to these two approaches, the DSGE approach is used to estimate the contributions of fiscal discretion to real GDP growth in the past. The DSGE approach utilizes the DSGE model with fiscal sector, developed in Chapter 2, and verifies the robustness of the results. In the following sections, I describe these approaches in more detail.

3.3.1 Bottom-up Approach

In the bottom-up approach, past discretionary fiscal measures and their budgetary impacts are collected from various government documents. These documents include: the Ministry of Finance's Convergence Programme, Fiscal Outlook, the Draft of the State Budget, and the explanatory memoranda of the proposed laws. Additionally, budgetary impacts are sometimes mentioned by the members of the government in the media. Budgetary impacts are usually ex-ante estimates of fiscal discretionary measures. Occasionally, these estimates are revised over time, e.g. in the new release of Fiscal Outlook the government adjusts budgetary impacts as macroeconomic conditions change or more information is available. To the extent possible, the latest estimates of budgetary impacts are collected for further analysis. For some fiscal measures, especially on the revenue side, it is possible to infer ex-post estimates. This concerns, for example, changes in indirect taxes: one can compare if an ex-ante estimate of the tax change is in line with the realized indirect tax collection and the evolution of the corresponding macroeconomic base (consumption). If these are not in line, then it is appropriate to ex-post revise the budgetary impact.

By recording fiscal measures, it is important to distinguish between two kinds of discretionary fiscal measures. Some fiscal measures have only temporary validity (e.g. adopted for one year), and some are approved as permanent measures. Temporary fiscal measures improve/worsen the government budget balance only through the time of their validity; thus, after their expiration or cancellation, it is important to notice that the government budget balance worsens/improves (the initial budgetary impact is reversed), and this should be reflected in any meaningful fiscal analysis. Thus, the budgetary impacts of temporary measures are recorded twice: at the start and after their end (with the opposite sign), whereas for permanent measures, it is important to record only the initial budgetary impact.

There is an issue with the bottom-up approach regarding discretionary fiscal measures on the expenditure side of the government budget. Some relevant expenditure fiscal measures are missing in government documents or their impacts are not stated. In the Czech Republic, this is usually the case of government investment, which is quite volatile over time, meaning that government investment exhibits periods of austerity and stimulation, and thus such fiscal discretion is not explicitly mentioned in government documents. Thus, omitting discretionary measures in government investment would lead to biased and incomplete results. Therefore, past discretionary fiscal measures for expenditure categories of the government budget (for consistency, not only for government investment) are approximated by the deviations from their long-term trend, more specifically by annual changes in these deviations (so as to reflect annual changes in the government budget).

The starting point to approximate fiscal discretion for a selected expenditure category is to calculate the deviation of the value of the selected expenditure (E_t) from the level of its autonomous trend (AE_t^j).

$$ED_t^j = E_t^i - AE_t^j, \ j \in \{1, 2\} \tag{3.1}$$

The autonomous trend of the selected expenditure category (AE_t) is modeled in two alternative versions, once as the trend in the level of expenditure, and then as the trend in the expenditure relative to GDP:

$$AE_t^1 = \tau_t^{HP}(E_t) \tag{3.2}$$

$$AE_t^2 = \tau_t^{HP}\left(\frac{E_t}{GDP_t}\right) * GDP_t \tag{3.3}$$

The trends are calculated according to the Hodrick-Prescott filter with a smoothing parameter of 30 for annual data.[3] The size of fiscal discretion for the selected expenditure category (FD_t^j) is given by an annual change in the deviations from the autonomous trend:

$$FD_t^j = ED_t^j - ED_{t-1}^j \tag{3.4}$$

In order to work with more disaggregated data, total government expenditure is divided into several expenditure categories: government consumption, government investment, social benefits other than unemployment benefits, and other structural expenditure. Unemployment benefits and interest payments are excluded from the analysis. Unemployment benefits is one of the few expenditure categories that fluctuates with the business cycle and is not understood as fiscal discretion. Interest payments are excluded because this commitment is mainly inherited from the past, and the government has quite limited power to influence the interest rates paid on government debt. Furthermore, one-off expenditures with no effect on current demand are excluded, and in the case of the Czech Republic, this is represented by: selected capital transfers (to Consolidation Agency, Railways, unconventional state guarantees), property settlement with churches, and the leasing of military equipment. Two so-called re-routing categories, social insurance paid by the government for state insurees and subsidies to renewable energies, are also excluded since these categories have exact counterparts on the revenue side of the government budget.

[3] To minimize the issue of the end-point bias of the HP filter, the relevant time series begin in 1995 and are extended into the future with the CNB fiscal forecast. The choice of smoothing parameter for the HP filter is adopted from the ESCB method of cyclical adjustment of budget balances.

When all fiscal discretion on the expenditure side is summed and deducted from the sum of all discretionary revenue measures, then one arrives at the total bottom-up fiscal discretion.

3.3.2 Top-down Approach

In the top-down approach, fiscal discretion is identified from the aggregate fiscal data, namely from so-called fiscal stance. Fiscal stance is defined as the annual change in the general government structural balance. A positive number indicates fiscal restriction and a negative number indicates fiscal expansion. The starting point to calculate the government structural balance is to estimate the cyclically-adjusted budget balance, which is the hypothetical government budget balance if the economy was at its potential level. The cyclically-adjusted budget balance less the one-off measures[4] gives the government structural balance. Although the top-down approach does not provide fiscal discretion for disaggregated fiscal categories (which are relevant for further analysis in this chapter), this method is helpful to cross-check total fiscal discretion, which is derived by the bottom-up approach.

The cyclically-adjusted budget balance can be estimated by several methods. In my analysis, I use two common methods: the one developed by the European Commission (Mourre, Astarita, and Princen 2014) and the ESCB method (Bouthevillain et al. 2001).

The European Commission Method

According to the European Commission method (henceforth EC), the cyclically-adjusted balance is the ratio of the general government balance to GDP that would occur if the economy was operating at its potential level:

$$cab_t = \frac{BB_t}{Y_t} - cc_t = \frac{BB_t}{Y_t} - \varepsilon * OG_t, \tag{3.5}$$

in which BB_t is the nominal government budget balance in year t, Y_t is the nominal GDP, cc_t is the cyclical component, ε is the budgetary sensitivity parameter, and OG_t is the output gap. The output gap represents the economy's cyclical position – the difference

[4] One-off measures include extraordinary revenue or expenditure, represented in the Czech Republic by the following: one-off non-tax and capital revenues (privatization proceeds, the sale of frequency bands to mobile operators, emission permits), subsidies to transformation institutions, Green Savings Programme, selected capital transfers (to Consolidation Agency, Railways, Deposit Insurance Fund, unconventional state guarantees), property settlement with churches, and the leasing of military equipment.

between actual and potential real output, expressed in percentage points of potential real output. The output gap is not observable and thus one needs to resort to an estimate of the potential output, e.g. employing the Cobb-Douglas production function.

The budgetary sensitivity parameter is computed as follows:

$$\varepsilon = \varepsilon_R - \varepsilon_G = \left(\sum_{i=1}^{4} \eta_{R,i} \frac{R_i}{R} - 1 \right) \frac{R}{Y} - \left(\eta_{G,U} \frac{G_U}{G} - 1 \right) \frac{G}{Y} \tag{3.6}$$

in which ε_R and ε_G are revenue and expenditure sensitivity parameters, η's are the elasticities of the individual revenue items (personal and corporate income tax, indirect taxes, and social contributions) and one expenditure category (unemployment benefits) to the output gap, R_i/R is the individual revenue category in current taxes, R/Y is the share of current taxes in GDP, G_U/G is the share of unemployment benefits in primary expenditure[5] and G/Y is the share of primary expenditure in GDP.

The elasticities, which are necessary to compute the budgetary sensitivity parameter, are estimated in a two-step procedure. First, the elasticity of the individual revenue or expenditure item with respect to the relevant macroeconomic base is calculated, and then the elasticity of the relevant macroeconomic base with respect to the output gap is obtained. These partial elasticities are then multiplied to obtain the overall elasticity of the individual fiscal item with respect to the output gap. The values of partial and overall elasticities for the Czech Republic are listed in Table 3.2 in the Appendix.

Generally, if the elasticities are close to one, then the budgetary sensitivity parameter is roughly represented by the ratio of non-cyclical expenditure[6] to GDP. The reasoning is the following. The revenue sensitivity parameter is usually close to zero because the revenue to GDP ratio stays broadly stable over the business cycle, e.g. government revenues are cyclical. On the other hand, the expenditure sensitivity parameter is negative and equals approximately the ratio of non-cyclical expenditure to GDP. The ratio of non-cyclical expenditure to GDP varies over the business cycle, rising in recessions and falling in booms. As for the Czech Republic, the budgetary sensitivity parameter, calculated according to the formula in 3.6, is roughly 0.3[7].

[5] Total current expenditure without interest payments paid on government debt.

[6] Total government expenditure less unemployment benefits, as these are considered to be the only cyclical expenditure.

[7] According to the Ministry of Finance (Lang and Mareš 2015), the estimate for budgetary sensitivity parameter is approximately 0.4.

The European Central Bank Method

The ESCB method, also labeled as the disaggregated approach, is based on the cyclical relationship between individual budget categories and their relevant macroeconomic bases. Generally, the evolution of macroeconomic bases is not necessarily synchronized with the output gap. This concerns mainly labor market variables, which usually record some delay in their behavior as compared to GDP. This also means that the cyclical components of individual budget categories in the ESCB method are allowed to have different contributions to the overall cyclical component of the government budget over time, as opposed to the EC method.

The same individual budget categories as in the previous method are considered: personal and corporate income tax, indirect taxes, social contributions, and unemployment benefits. Their relevant macroeconomic bases are analogous to the EC method, and are listed in Table 3.2 in the Appendix. One minor refinement is that the macroeconomic base for the wage bill is further disaggregated into the average compensation of employees and employment.

According to the ESCB method, the cyclically-adjusted budget balance is calculated as follows:

$$CAB_t = BB_t - \sum_j B^j_{c,t} = BB_t - \sum_j B^j_t \varepsilon_{B^j,V^j} \frac{V^j_t - V^{j*}_t}{V^{j*}_t} \tag{3.7}$$

in which j stands for the individual budget category, $B^j_{c,t}$ is the cyclical component of the individual budget category in year t, B^j_t denotes the actual nominal value of the individual budget category, ε_{B^j,V^j} is the elasticity of individual budget category relative to the corresponding macroeconomic base V^j, and V^{j*}_t is the trend value of the macroeconomic base in real terms and is identified by the Hodrick-Prescott filter[8]. The elasticities of the individual budget category with respect to the corresponding macroeconomic base are set in accordance with the EC method; for details, see the first column with the values in Table 3.2.

3.3.3 DSGE Approach

Another approach, suitable to identify fiscal discretion, rely on a DSGE model with fiscal sector, presented in Chapter 2. This model comprises a comprehensive set of fiscal shocks, occurring both on revenue and expenditure side of government budget (for details

[8]According to the ESCB method, a smoothing parameter of 30 is chosen for annual data.

see equations 2.11–2.12). In this approach the Kalman filter is run on historical observed data, and structural shocks of the DSGE model are retrieved, including the fiscal ones. Then, for the purpose of my analysis it is relevant to analyze the contributions of fiscal shocks on real GDP growth in the past. These contributions of fiscal shocks to real GDP growth represent estimated impacts of fiscal discretion. Similarly to the top-down approach, this DSGE approach serves as a verification tool for the results obtained by the bottom-up approach.

3.4 The Results

In this section, fiscal discretion in the Czech Republic is derived according to two methods: the bottom-up approach and the top-down approach. For the robustness of the results, two different versions of fiscal discretions are computed and compared. Furthermore, the impacts of fiscal discretion on real GDP are calculated by two methods. Firstly, the impacts of fiscal discretion are computed using the set of fiscal multipliers for different government revenue and expenditure categories. The fiscal multipliers used for the Czech Republic are taken from Ambriško (2016) and also stated in Chapter 2.4.1. Secondly, the impacts of fiscal discretion on real GDP growth are retrieved directly from the DSGE model presented in Chapter 2. Subsequently, past fiscal discretion is analyzed with respect to the business cycle to inspect the stabilization role of fiscal discretion. Lastly, it is shown that if the Czech government had pursued more growth-friendly fiscal discretion in the past, then real GDP could have grown faster.

3.4.1 Fiscal Discretion

In my analysis[9], fiscal discretion is understood as the changes in taxes and government spending aimed at influencing macroeconomic developments, and these changes are other

[9] The underlying fiscal series used in my analysis are vintage data from April 2018, as published by the Czech Statistical Office. Further, the CNB's spring 2018 fiscal forecast was used to extend several fiscal series, especially in order to avoid the end-point bias of the HP-filter.

Using real-time data for the analysis is somewhat limited. Although real time data are available for relevant time series (real GDP, the components of government revenue and expenditure), this is not the case for the budgetary impacts of fiscal measures. For some fiscal discretionary measures there are no historical revisions of budgetary impacts. Thus, the real time analysis would mainly be driven by the revisions to underlying time series, and only then, to some extent, by occasional revisions to budgetary impacts. Nevertheless, employing real time data could bring additional insight into the implementation of fiscal discretion by policymakers in the past.

than those induced by the business cycle. I measure fiscal discretion by two approaches: the bottom-up and the top-down.

Bottom-up Approach

The budgetary impacts of past revenue discretionary measures, expressed as a percentage of nominal GDP, are depicted in Figure 3.1 in the Appendix. The majority of revenue measures concern changes in direct and indirect taxes, whereas adjustments to social contributions and other taxes were less prevalent.

As explained earlier in Section 3.3.1, the budgetary impacts of expenditure measures are approximated by annual changes in the deviations of selected expenditure from its autonomous trend, which is identified by two alternative methods. Once autonomous trend is modelled as the trend in the level of expenditure, and subsequently autonomous trend is modelled as the trend in the expenditure relative to GDP. Two expenditure discretions correspond to these two alternative autonomous trends; labeled as "expenditure discretion A" and "expenditure discretion B", and presented in Figures 3.2 – 3.3. Generally, expenditure discretion is more focused on government investment and government consumption. In the beginning of the analyzed period (2001–2004), several sudden shifts in other structural expenditure occurred. The changes in other social benefits are less frequent, and their budgetary impacts are smaller compared to other fiscal categories.

In combining the revenue and expenditure discretions, one obtains the total bottom-up fiscal discretion. As two versions of expenditure discretion were calculated, there are also two alternative versions of the total bottom-up fiscal discretion, presented in Figures 3.4 – 3.5. Average fiscal discretion over the analyzed period is close to zero for both versions of fiscal discretions. This suggests that overall fiscal discretion is roughly neutral in the long-run, at least with respect to its budgetary impacts.

As regards total fiscal discretion, sizeable budgetary impacts were recorded particularly in years 2001–2004, 2009–2010, 2013, and 2016. These coincide with the following periods and major events: EU accession in 2004; fiscal stimulus in 2009 as a response to the economic crisis in 2008, which subsequently reversed into fiscal consolidation in 2010; the next fiscal consolidation occurring in 2013; and a sudden drop in investment activity in 2016 after the end of the previous Programme period for drawing EU funds (a multi-year EU budget over 2007–2013).

Top-down Approach

Total fiscal discretions as identified by the top-down approach, using two different methods, are depicted in Figure 3.6. The top-down approach is useful to verify the fiscal discretion that was derived by the bottom-up approach. Both the EC and ESCB methods give qualitatively similar results in respective years, i.e. fiscal stances move in the same direction. Nonetheless, the fiscal stances for 2015 may not be very conclusive, since the fiscal stance by the EC method is close to zero.

As a robustness check, a different budgetary sensitivity parameter is used for the EC method, amounting to 0.4, which is a slightly higher value than in the baseline setting (0.3). This value is used, for example, by the Ministry of Finance (Lang and Mareš 2015). Figure 3.7 compares the fiscal stances for the baseline and alternative setting of the budgetary sensitivity parameter. The differences do not appear large, but in some years the assessment of fiscal discretion changes. To be more specific, in 2005 and 2006 fiscal discretion is more expansionary and deviates from the ESCB method. In 2009 fiscal discretion is distinctly smaller, compared to both the baseline setting and the ESCB method. In 2015, the fiscal discretion turns into an expansionary position, as opposed to the ESCB method, which identifies fiscal discretion as restrictive. Overall, the results for the baseline setting of the budgetary sensitivity parameter are more in line with the ESCB method, and therefore they represent a preferred choice.

Average fiscal discretion over the analyzed period is slightly positive, amounting 0.25% of GDP for both the EC method and the ESCB method. This is somewhat different result compared to the bottom-up approach, where average fiscal discretion is close to zero. Some difference might be explained by the fact that some revenue measures might be missing in the bottom-up approach due to difficulty in their collection.

Fiscal discretions identified by the bottom-up and top-down approaches are plotted in Figure 3.8. Generally, both methods yield similar results, which can be confirmed by the measured correlation between the respective time series over the sample period of 2001–2017. The pair-wise correlations between the measures of the fiscal stances and bottom-up discretions are high, reaching values slightly above 0.9.[10] The highest correlation (0.94) is recorded between the ESCB fiscal stance and the bottom-up approach, where expenditure discretion is approximated by the deviation from the trend in the expenditure relative to GDP ("Discretion B").

[10]Given the number of observations (17 years), the measured correlation is significant at the 1% level when it is higher than 0.61.

Altogether, the results of the top-down approach suggest that the identification of fiscal discretion by the bottom-up approach may be representative enough. In the next section, fiscal discretion derived by the bottom-up approach is taken as a foundation for further analysis.

3.4.2 The Impacts of Fiscal Discretion: the Bottom-up Approach

Having derived fiscal discretion by the bottom-up approach, the impact of fiscal discretion on the economy can be estimated by using fiscal multipliers. The size of the fiscal discretion of a selected revenue or expenditure category, as expressed as a percentage of nominal GDP, is multiplied by the fiscal multiplier valid for the respective fiscal category. For this calculation, I use my own set of fiscal multipliers for different tax revenues and government expenditures, as available in Ambriško (2016) or in Table 2.4 in the previous chapter.

Focusing on the immediate effects of fiscal discretion on real GDP growth, the fiscal multipliers valid for the first year are used. Alternatively, dynamic fiscal multipliers, valid for several years, could be applied, as that would reflect the fact that some fiscal measures are valid for a longer period, and therefore the effects of fiscal discretion on economic activity can propagate over time. Calculated this alternative way, the final impact on GDP in a given year may be blurred by the carry-over effects of fiscal discretion propagating from the past. Usually, the most pronounced effects of fiscal discretion occur in the first year in which fiscal measures are implemented, and thus the use of only first-year fiscal multipliers may be a reasonable simplification.

The impacts of fiscal discretion are presented in Figures 3.9–3.10. As mentioned earlier, two versions of fiscal discretion were derived from the bottom-up approach, which translates also into two versions of the impacts of fiscal discretion. The results show that fiscal discretion in the Czech Republic was used frequently, and some sizeable impacts on real GDP growth were recorded, especially in years 2004, 2009, and 2016, with estimated impacts reaching about 1.0–1.5 p.p. in real GDP growth. These impacts can be mainly explained by the following fiscal measures: in 2004, value added taxes were harmonized with the EU rules, in 2009 temporary rebates on social insurance were introduced for employers in response to the economic crisis, and in 2016 there was a sudden drop in investment activity related to the end of the multi-year Programme period for drawing EU funds.

Nevertheless, the average impacts on real GDP growth over the analyzed period are close to zero for both versions of fiscal discretions. This suggests that overall fiscal discretion was roughly neutral in the 2001–2017 period with respect to real GDP growth. However, in the forthcoming section 3.4.5, I argue that if fiscal discretion had had a better growth-friendly composition, then real GDP could have grown faster in the past. This would also mean that fiscal discretion in the past did not have to be neutral, but rather slightly positive, with respect to economic growth.

3.4.3 The Impacts of Fiscal Discretion: the DSGE Approach

The impacts of fiscal discretion derived by the bottom-up approach can be cross-checked by the DSGE approach. For this purpose I employ the DSGE model with a fiscal sector developed in Chapter 2. Figure 3.11 shows which structural shocks of the DSGE model explain the movements in real GDP growth between 2001 and 2017. The black line in this figure represents annual real GDP growth in the quarterly frequency, expressed as the deviation from its trend growth, which is identified by the HP filter with a smoothing parameter set at 1600. The contributions of individual fiscal shocks, specified by the innovations in equations 2.11–2.12, are aggregated and shown in brown bars. Quarterly fiscal contributions are averaged to yearly frequency in order to compare the impacts computed by the bottom-up approach. This is shown in Figure 3.12, with the results of the DSGE approach labeled as "Fiscal discretion DSGE".

Qualitatively, the impacts of fiscal discretion obtained using the DSGE approach are very roughly in line with the impacts derived by the bottom-up approach. Some differences are noticeable with respect to the size of the impacts, which are lower in the DSGE approach. The highest impact with the DSGE approach is found in 2010, amounting to 0.6 percentage points of the real GDP growth. Further, in the DSGE approach the impact of fiscal discretion in 2009 is relatively low compared to the bottom-up approach. Fiscal stimulus, which was adopted in 2009 in response to the economic crisis, seems to be captured by the DSGE model in the real GDP growth with some lag; emerging only in the second half of 2009 and continuing in 2010 (see Figure 3.11). These delayed contributions might be due to the persistence nature of the fiscal rules, which are specified in the DSGE model. Thus, in this DSGE approach the impacts on real GDP growth may be blurred by the carry-over effects of fiscal discretion propagating from the past.

There are some similarities in the results for both approaches. Similarly to the bottom-up approach, the DSGE approach implies that the average impact of fiscal discretion on real GDP growth over the period analyzed is close to zero, providing more support to the finding that fiscal discretion was roughly neutral in the 2001–2017 period. Further, there are low pair-wise correlations between the impacts of fiscal discretion using the DSGE approach and the bottom-up approach (either Discretion A or Discretion B), reaching values slightly below 0.5.

3.4.4 Fiscal Discretion over the Business Cycle

Fiscal discretion itself is able to mute or amplify the business cycle. Fiscal austerities and fiscal expansions can occur in positive or negative economic conditions. This means that fiscal discretion can be pro-cyclical, counter-cyclical or sometimes a-cyclical. Generally, the preferred role for fiscal discretion would be counter-cyclical, meaning fiscal austerities in positive economic conditions and fiscal expansions in negative economic conditions, in order to smooth out business cycle fluctuations. I inspect the stabilization role of Czech fiscal discretion by comparing the impacts of fiscal discretion on real GDP growth against the output gap, to ascertain whether or not those two tend to move together in the same direction.

The impacts of fiscal discretions on real GDP growth with the output gap are depicted in Figure 3.12. There are two estimates of the output gap, according to the production function method[11] and the Hodrick-Prescott filter. The comparison of the impacts of fiscal discretions (by the bottom-up approach) with the output gap indicates that fiscal discretion in the Czech Republic was pro-cyclical in the years 2004, 2008, 2010, 2012–2013, and 2016–2017, whereas counter-cyclical in the years 2001, 2003, 2007, 2009, 2011, and 2014–2015. The results for remaining years 2002 and 2005–2006 are not clearly conclusive. This is because in 2002 and 2006 the impacts of two alternative fiscal discretions by the bottom-up approach have opposite signs, and in 2005 two estimates of the output gap attain similarly opposite signs.

Comparing the impacts of fiscal discretions using the DSGE approach with the output gap, several remarks can be made. The results for 2002 and 2006, which were inconclusive in the bottom-up approach, suggest that fiscal discretion was counter-cyclical in 2002 and cyclical in 2006. However, the results for some years become less clear when the impacts

[11] As it is applied in the CNB's macroeconomic forecast.

of fiscal discretions using the DSGE approach are taken into account. This is valid for 2003 and 2008, when fiscal discretion using the DSGE approach is roughly a-cyclical. Furthermore, in 2010 and 2017 fiscal discretion using the DSGE approach seem to be counter-cyclical.

Nonetheless, roughly in half of the sample fiscal discretion (by the bottom-up approach) was counter-cyclical, and in the second half pro-cyclical. Thus, no obvious link between fiscal discretion and the output gap can be distinguished, suggesting that, on average, Czech fiscal discretion has not contributed to stabilizing business cycle fluctuations. This statement can be also supported by pair-wise correlations measured between the impacts of fiscal discretion (in all versions, including the DSGE approach) and the output gap, which lie in a statistically insignificant range of -0.2 to 0.1.

From Figure 3.12 one can also notice that the business cycle in the Czech Republic was significantly influenced by fiscal discretion, especially in years 2009–2011 and 2016. An "anti-crisis" fiscal package in 2009 helped to curb the negative output gap, whereas fiscal consolidation in 2010 could have been somewhat lower so as to make the output gap closer to zero. Further fiscal consolidation in 2011 contributed to dampening the positive output gap in that year. Finally, a sudden drop in government investment in 2016 seems to be the main driver behind the negative output gap.

3.4.5 Desirable Fiscal Discretion

Past fiscal discretion did not need to have a suitable composition with respect to its consequences on economic growth. Perhaps there were times when the government might have placed excessive emphasis on fiscal instruments that are quite detrimental to real GDP growth, compared to certain other more growth-friendly fiscal instruments. An appropriate growth-friendly composition of fiscal discretion is what matters for the economy.

If past fiscal discretion in the Czech Republic had had a better growth-friendly composition, as suggested by Ambriško (2016) and computed in the previous chapter 2.4.2, then real GDP could have grown faster. The impacts of fiscal discretions, with a more desirable composition, on real GDP are shown in Figures 3.13–3.14. Two different versions emanate from two alternative specifications of fiscal discretions. The estimated cumulative gain in real GDP growth amounts to 1.9 p.p. over the 2001–2017 period with a desirable composition of fiscal discretion in version A, and 1.7 p.p. for fiscal discretion in version B.

Note that the hypothetical desirable composition does not perform better than the actual composition of fiscal discretion in all periods. This stems from the way in which the weights to fiscal instruments are assigned in the desirable fiscal discretion. These weights respect, besides so-called fiscal scores (recall Equations 2.20–2.21 in the previous chapter), also the actual shares of fiscal instruments in nominal GDP. This weighting scheme contributes to a more evenly distributed allocation of fiscal discretion over a wider spectrum of fiscal instruments. For instance, as regards fiscal discretion A in 2015, there was a significant part of fiscal discretion originating from a substantial increase in government investment. However, in the desirable composition of fiscal discretion more weight is also attached to other fiscal instruments (government consumption and tax revenues), which in the end results in a lower impact on real GDP growth as compared to the actual fiscal discretion.

To sum up, my results indicate an average annual loss of approximately 0.15 p.p. of real GDP growth due to the ineffective composition of fiscal discretion. The yearly loss may appear low, but in the long run the hypothetical cumulative gain represents a relevant issue that the government should consider when implementing fiscal discretionary measures. These results corroborate that the government is able to additionally support the economy by appropriately adjusting fiscal instruments.

3.5 Conclusion

In this chapter, I address three important issues related to fiscal discretion in the Czech Republic. The first issue concerns the impacts of fiscal discretion on the Czech economy in the past, and their size and sign. The second issue concerns the stabilization role of fiscal discretion, i.e. whether fiscal discretion helped to dampen business cycle fluctuations. The third issue is associated with the real GDP loss due to the ineffective composition of past fiscal discretion.

I identify fiscal discretion by combining various approaches. By the bottom-up approach, to the extent possible, past discretionary fiscal measures and their budgetary impacts are collected from official government documents, e.g. regular fiscal outlooks, updates of so-called Convergence Programmes, and explanatory notes to adopted laws, among others. On the expenditure side of the government budget, fiscal discretion is estimated by changes in the deviations of respective expenditures from their long-term trend. For robustness of the identification, the top-down approach is also used to measure the size of fiscal discretion, and in this approach, fiscal discretion is represented by the changes in the structural government budget balance.

Having derived the size of fiscal discretion, the impact of fiscal discretion on the economy is estimated by two methods. In the first method, the impact of fiscal discretion on real GDP growth is calculated using fiscal multipliers. For that purpose, I use my own set of fiscal multipliers for the Czech Republic, which is available in Ambriško (2016) and in the previous chapter 2.4.1. In the second method, I utilize the DSGE model with fiscal sector, developed in Chapter 2, to derive the contributions of fiscal discretion on the economy. I find that fiscal discretion in the Czech Republic was used frequently, and some sizeable impacts on real GDP growth are recorded, especially in years 2004, 2009 and 2016, with estimated impacts (which come from the bottom-up approach) reaching about 1.0–1.5 p.p. in real GDP growth.

As regards the cyclical aspect of fiscal discretion, I find with the bottom-up approach that fiscal discretion in the Czech Republic was pro-cyclical in years 2008, 2010, 2012–2013, and 2016–2017, whereas counter-cyclical in 2009, 2011, and 2014–2015. Therefore, an obvious link between fiscal discretion and the business cycle is not detected, suggesting that, on average, Czech fiscal discretion has not helped to stabilize business cycle fluctuations.

If past fiscal discretion in the Czech Republic had had a better growth-friendly composition, as suggested by Ambriško (2016), then real GDP could have grown faster. The estimated cumulative gain in real GDP growth amounts to approximately 1.8 p.p. over the 2001–2017 period. This result means that the average yearly loss of 0.15 p.p. of real GDP growth could be attributed to the ineffective composition of fiscal discretion. Hence, the government should carefully consider the composition of fiscal discretion when adopting new fiscal measures.

There are several possible avenues for future research. One could use a different set of fiscal multipliers to check the robustness of the conclusions concerning the economic impacts on real GDP growth and economic losses due to the ineffective composition of past fiscal discretion. The analysis could also be extended to include the effects of fiscal discretion on other relevant economic variables of interest, such as household consumption, investment, or labor market variables. Another important avenue of research is to examine the impacts of fiscal discretion on income distribution.

Appendix

3.A Tables and Figures

Table 3.1: Selected Fiscal Multipliers for the Czech Republic

	IMF*	OECD**	Ambriško (2016)
Expenditures			
Government consumption	0.4	0.3	0.6
Government investment	0.4	0.7	0.5
Taxes			
Labor tax	0.1	0.1	0.3
Social security contributions	-	-	0.4
Consumption tax	0.1	0.1	0.3
Capital tax	0.0	-	0.0

* GIMF model by the IMF - Klyuev and Snudden (2011)
** INTERLINK macroeconometric model by the OECD (2009)

Table 3.2: The Elasticities of Fiscal Items

Fiscal item	Macroeconomic base	Elasticity fiscal item w.r.t. macro.base	Elasticity macro.base w.r.t. output gap	Elasticity fiscal item w.r.t. output gap
Personal income tax	Wage bill	1.90	0.80	1.52
Corporate income tax	Operating surplus	1.00	1.44	1.44
Indirect tax	Priv.consumption	0.88	1.00	0.88
Social contributions	Wage bill	0.90	0.80	0.72
Unemployment benefits	Unemployed	0.88	-2.67	-2.35

Figure 3.1: Sum of Past Revenue Measures (% GDP)

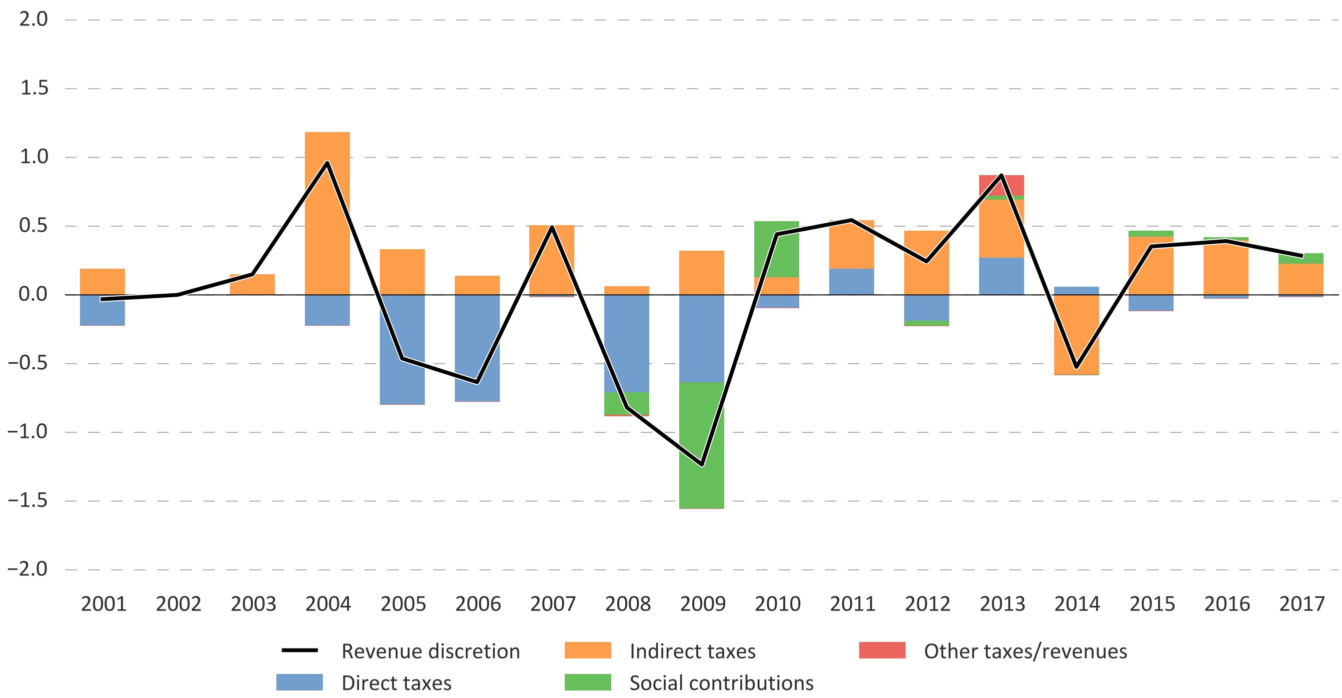


Figure 3.2: Sum of Past Expenditure Measures (% GDP)

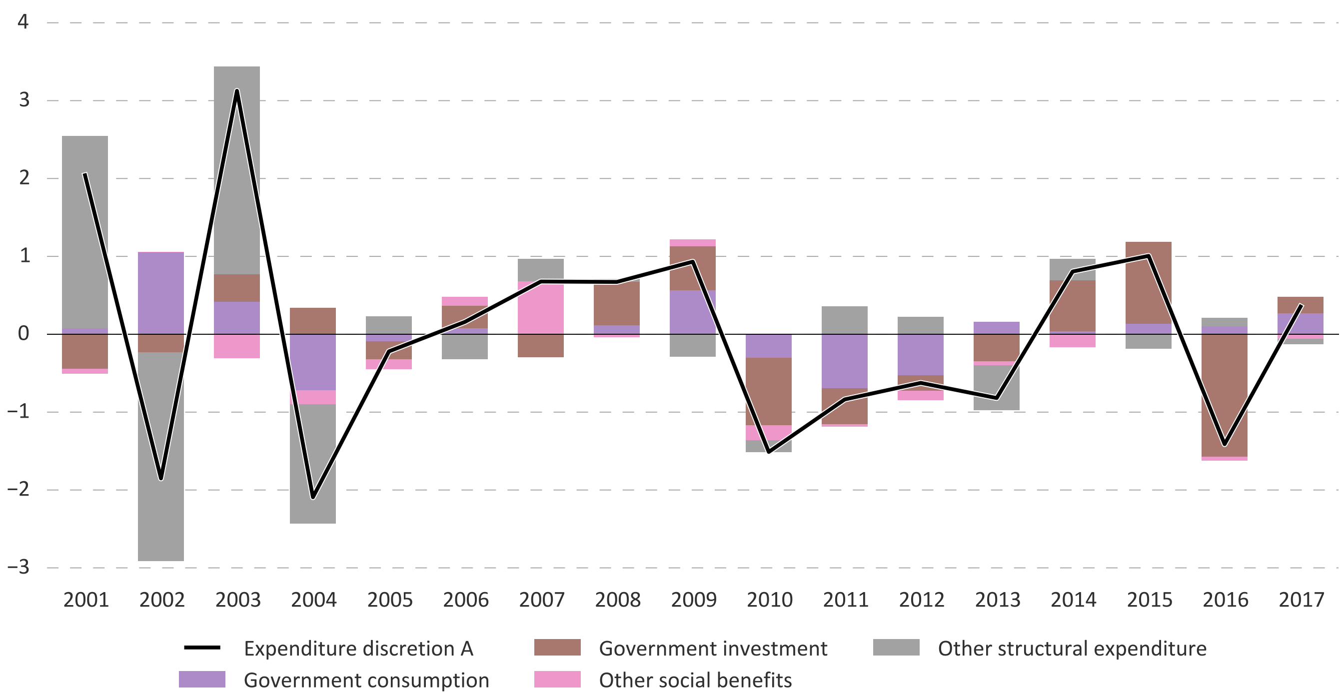


Figure 3.3: Sum of Past Expenditure Measures (% GDP)

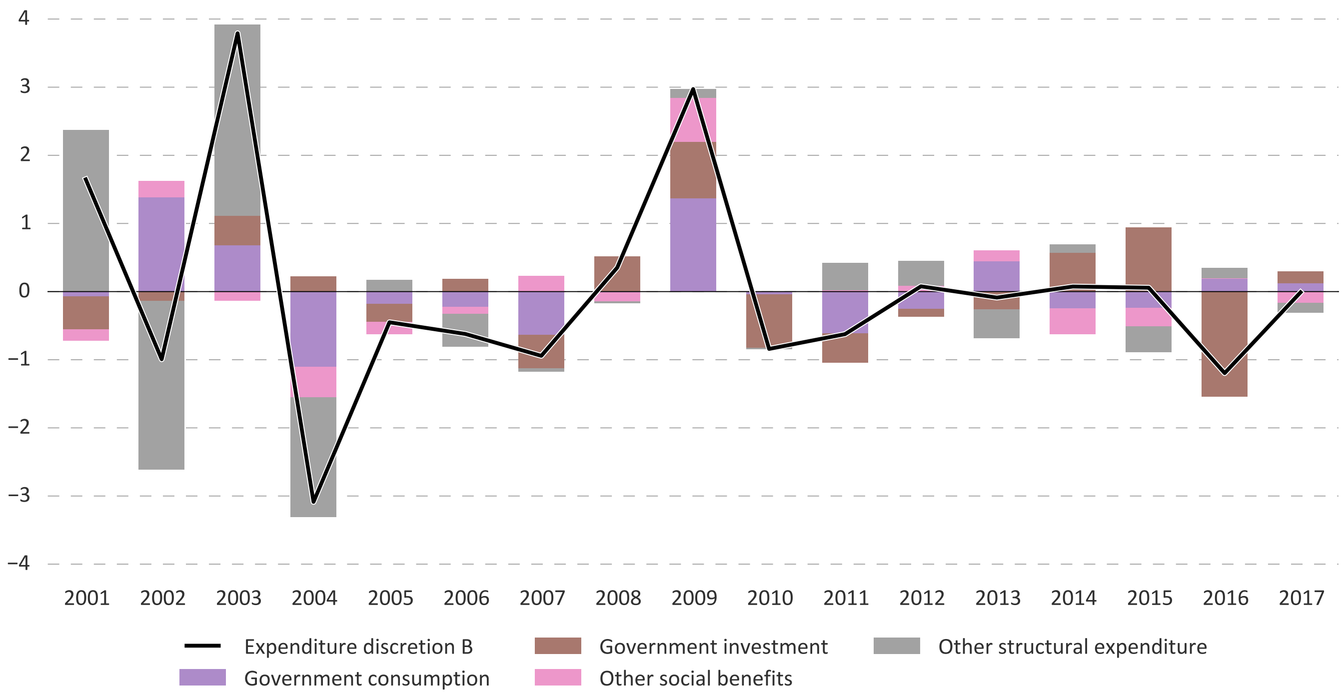


Figure 3.4: Sum of Past Measures (% GDP)

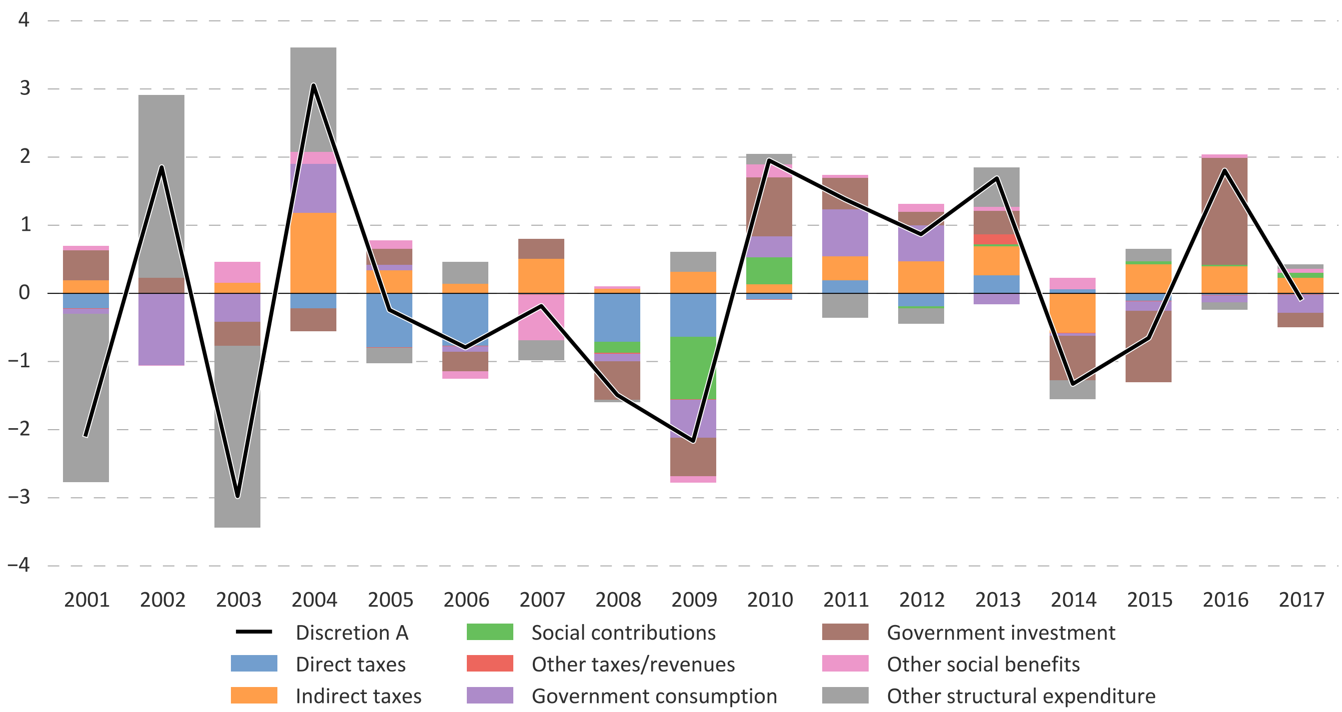


Figure 3.5: Sum of Past Measures (% GDP)

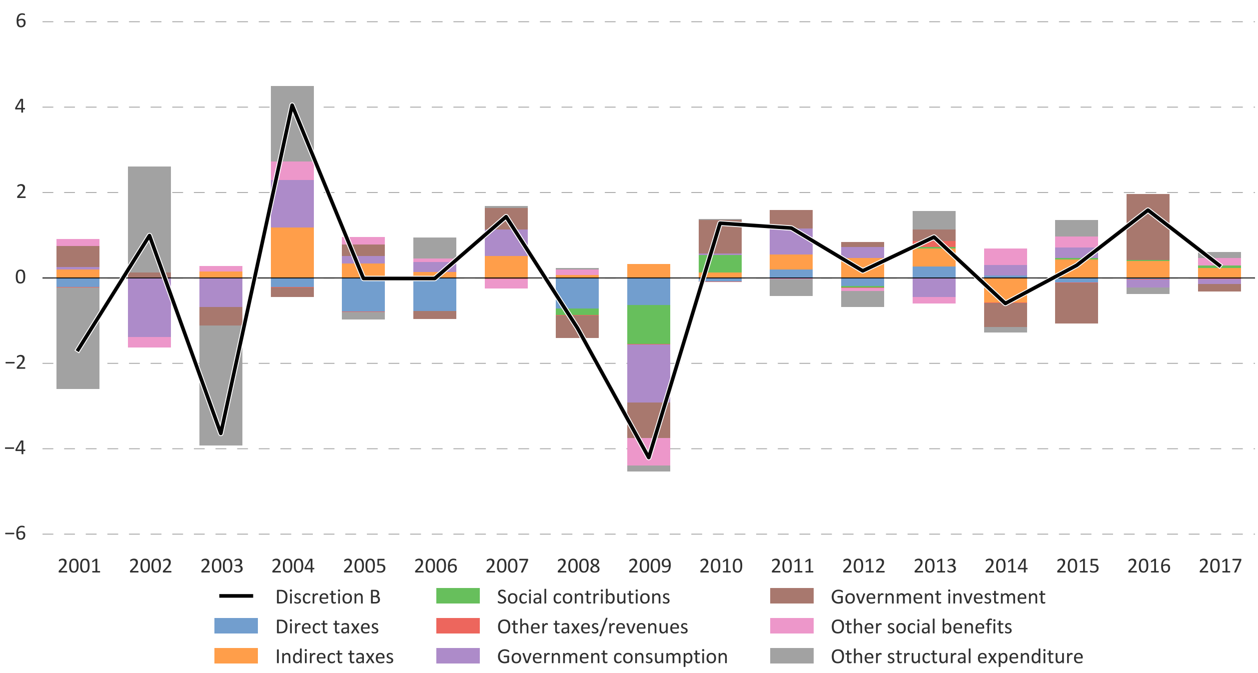


Figure 3.6: Annual Changes in Structural Balance of the Public Budgets (% GDP)

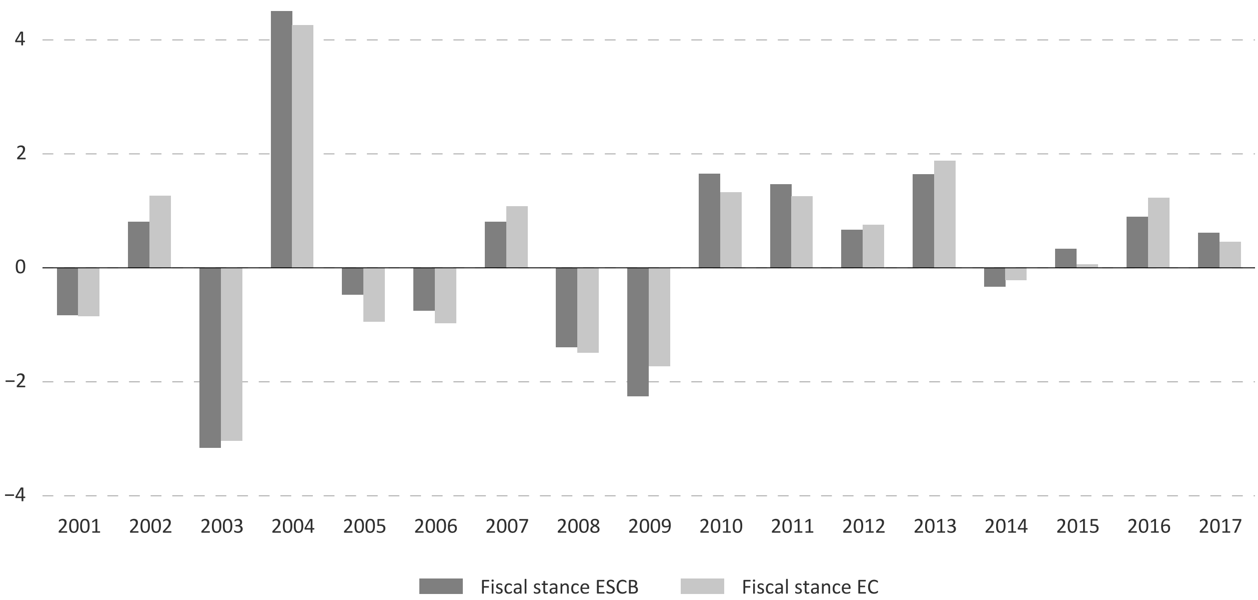


Figure 3.7: Sensitivity of Fiscal Stance by the European Commission Method (% GDP)

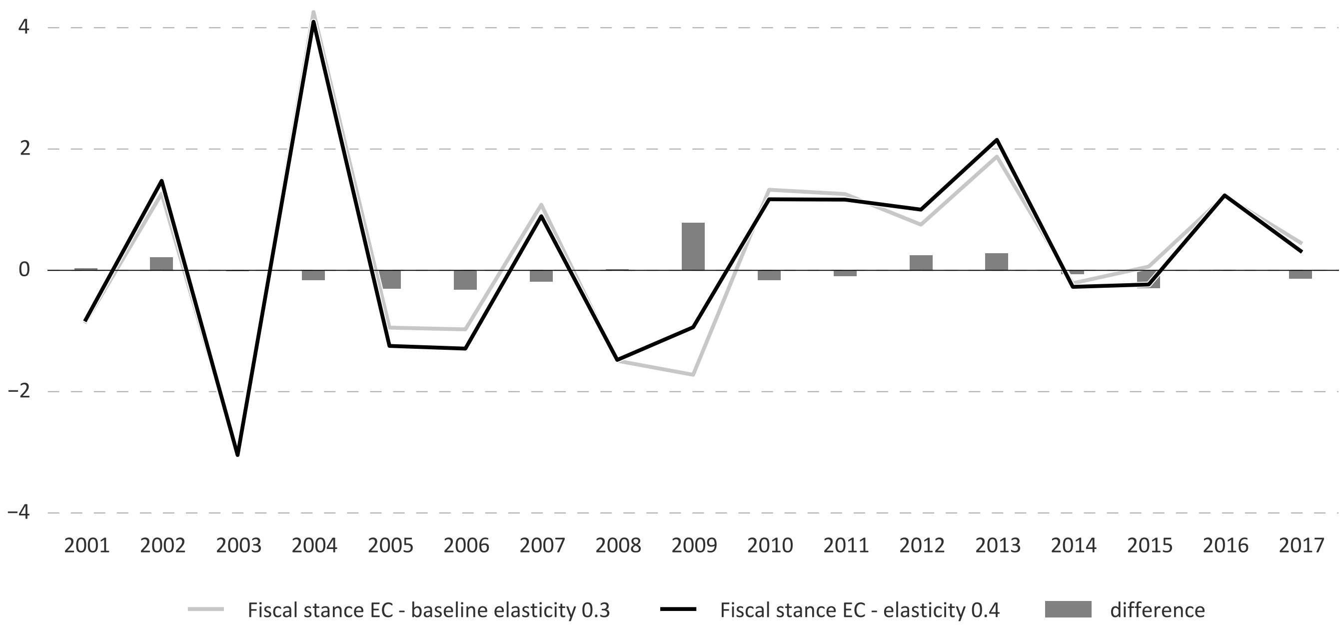


Figure 3.8: Bottom-up and Top-down Approaches Compared

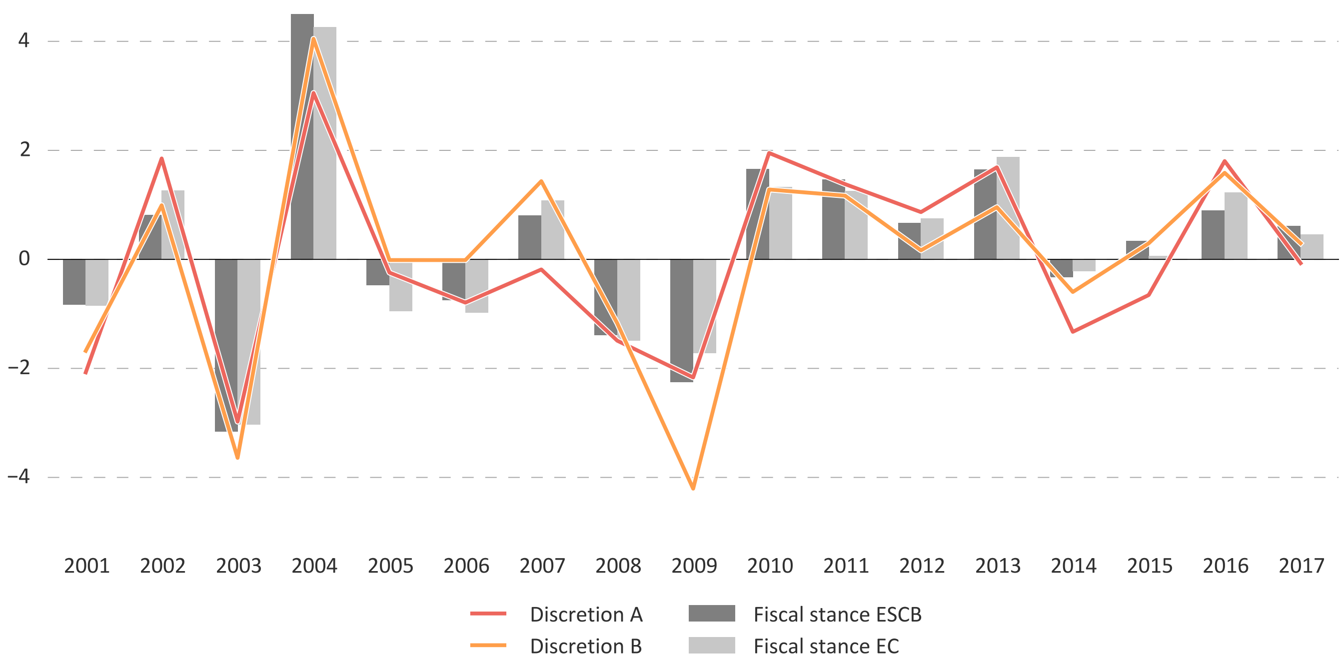


Figure 3.9: Impacts of Fiscal Discretion to Real GDP

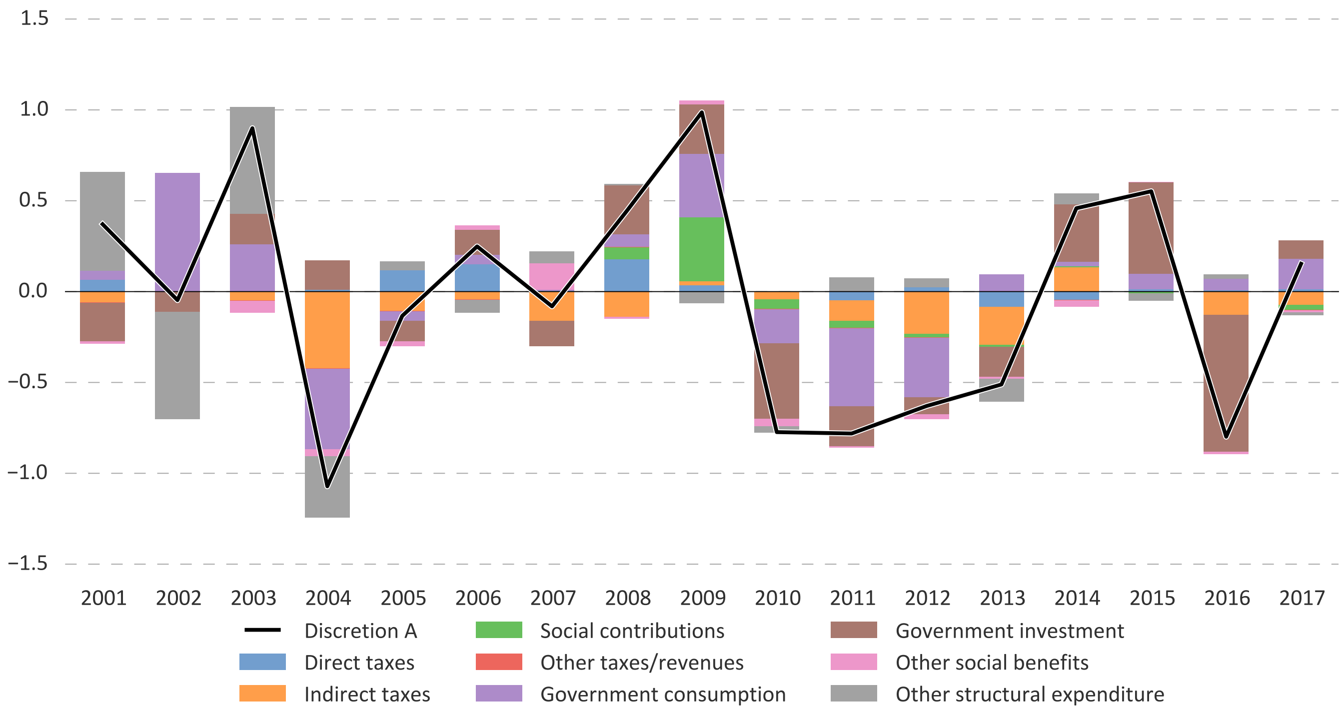


Figure 3.10: Impacts of Fiscal Discretion to Real GDP

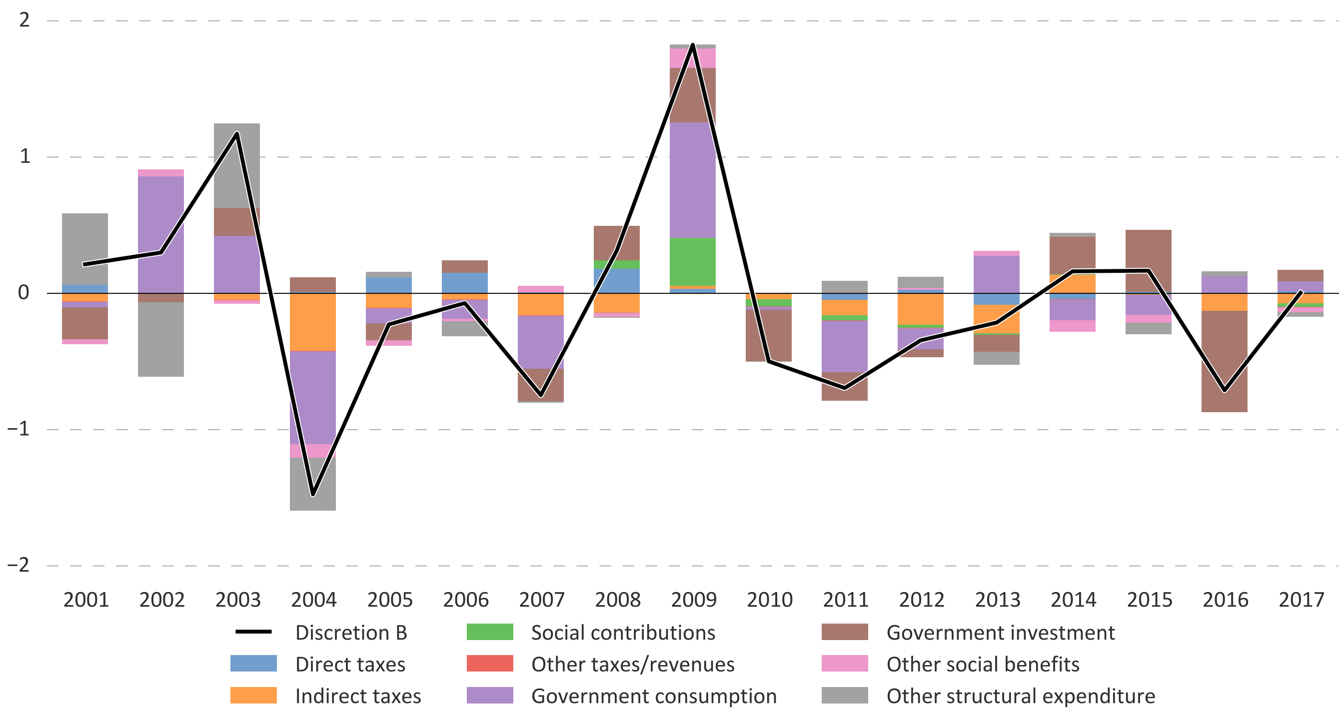


Figure 3.11: Real GDP growth, Decomposed into the Contributions of Structural Shocks

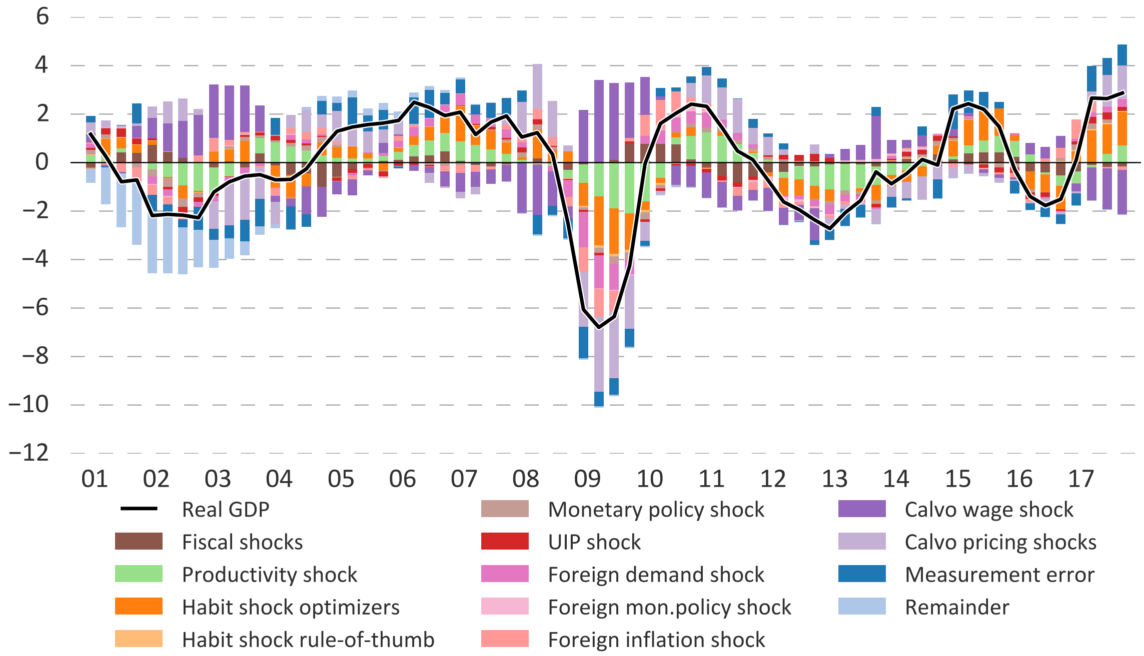


Figure 3.12: Fiscal Discretion over the Business Cycle

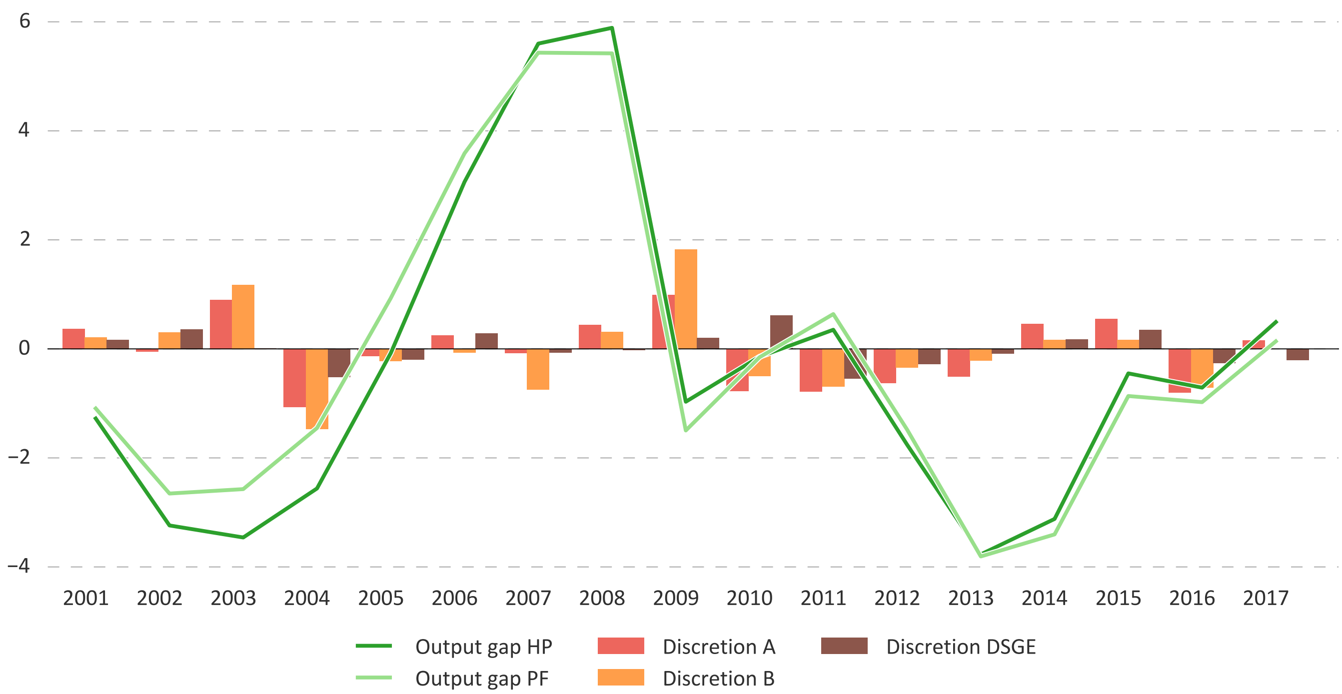
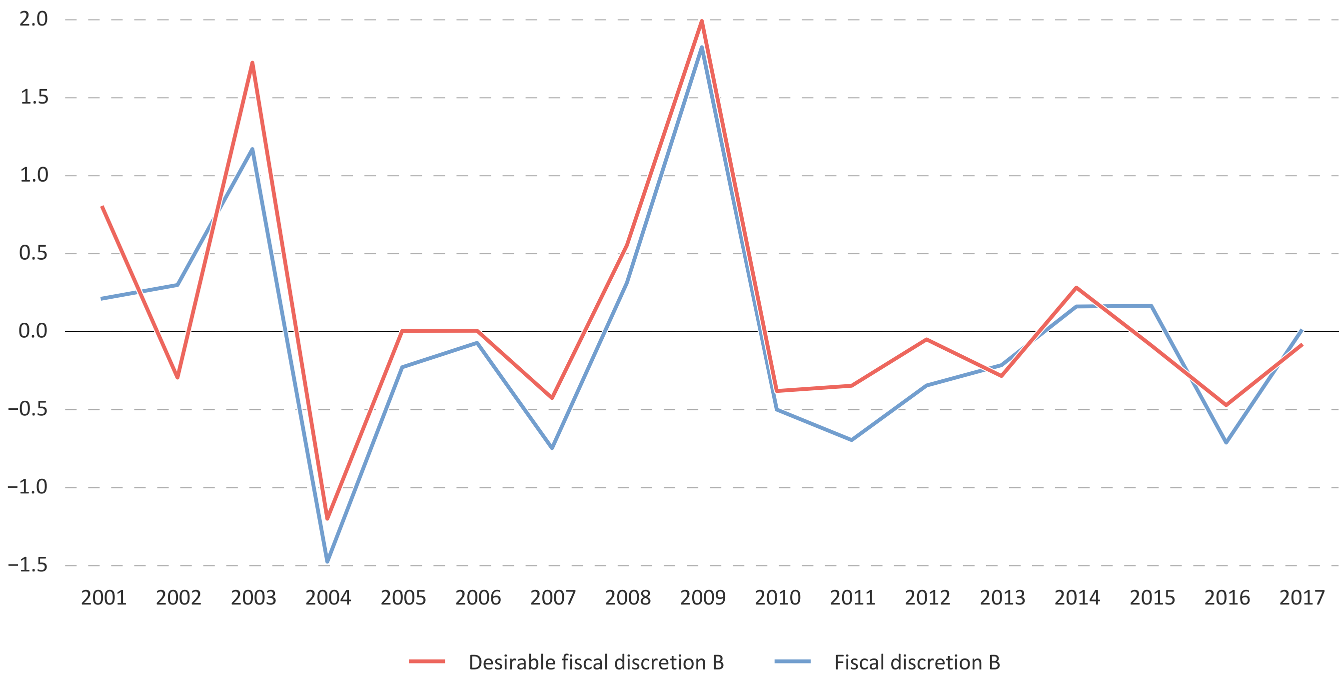


Figure 3.13: Impacts of Desirable Fiscal Discretion to Real GDP

Figure 3.14: Impacts of Desirable Fiscal Discretion to Real GDP



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