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The role of government size**

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Floating or fixed exchange rates: The role of government size

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Abstract

This paper contributes to the ongoing debate on the reform of the international monetary system by evaluating the net welfare gains of monetary policies with flexible exchange rates over a fixed exchange rate as a function of a country's public sector size. The argument goes back to Anna Schwartz (2000), who linked the role of government size to the viability of a fixed exchange rate regime, as a response to reform plans of the international monetary system by the [Bretton Woods Commission \(1994\)](#). Using a standard New Keynesian small open economy model to quantify this conjecture, three main results emerge: (1) The net welfare gains are increasing in government size; (2) The optimal simple Taylor rule attains a non-negligible role to stabilizing fluctuations in the nominal exchange rate; (3) Increasing public sector size reduces output variability irrespective of the exchange rate policy.

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“The growth of government itself has destroyed the viability of a gold standard (Schwartz, 2000).”

1 Introduction

In the aftermath of the global financial crisis of 2008 excessive exchange rate fluctuations have been identified as one of the main structural weaknesses in the current international monetary arrangements, such that efforts to reform the international monetary system regained traction (Palais-Royal Initiative, 2011). Accordingly, the vision of such a reform would imply for some countries a return to an exchange rate regime with a fixed rule for convertibility between national currencies.¹ In response to previous similar reform plans, Schwartz (2000) asserted that the appeal of fixed exchange rate regimes has declined with the substantial increase of public sector size in the 20th century.² The goal of this paper is to provide a quantitative exploration of this conjecture.

The discussion on the relative merits of floating versus fixed exchange rate regimes and on optimal monetary policy in open economies has a long-standing tradition in international macroeconomics. An advantage of flexible exchange rates is that they allow international relative prices to realign quickly without the need for sluggish adjustments in domestic inflation. Being primarily concerned with the *level* of the net welfare gains from exchange rate flexibility, several important papers have found that a complete stabilization of domestic inflation without explicitly considering the exchange rate in the interest rate rule, i.e., with a fully floating exchange rate, results in the optimal monetary policy.³ This finding has been cautioned by several authors, since it is an outcome which is sensitive to many underlying factors, like the source of volatility, the assumption on local or producer currency pricing or the role of the financial sector. For example, Kollmann (2005) shows that a fixed exchange rate may be optimal as it completely eliminates shocks to uncovered interest parity.⁴

By contrast with this literature, the present paper focuses on the quantitative implications of government size when changing the exchange rate regime from flexible to fixed. This question has received much less attention in the literature. The argument goes back to Schwartz (2000), who attributed the durability and viability of the gold standard in the late 19th and early 20th century, besides of its stabilizing role as nominal anchor, mainly to the fact that the share of government spending in total output was small, such that the adjustment of the private sector was facilitated.

With regard to this fact, in Figure 1 the size of the public sector expressed by the general government expenditures (left figure) and revenues (right figure) as a share of GDP are plotted. The fiscal data stems from a recent compilation by Mauro, Romeu, Binder, and Zaman (2015), and thereof a sample of annual data between 1950 and 2010 for 22 OECD countries is considered.⁵ Median es-

¹For instance, former Federal Reserve Chairman Paul Volcker prominently called for a new exchange rate regime in the style of Bretton Woods. See <http://bit.ly/1BpZK0o>, downloaded June 19, 2014.

²In previous episodes of the post-Bretton Woods period there have appeared similar reform plans. For instance, the Bretton Woods Commission (1994) proposed a new framework for foreign exchange rates, which aimed at mitigating their influence on market fluctuations and at shifting the management of their movements to monetary authorities.

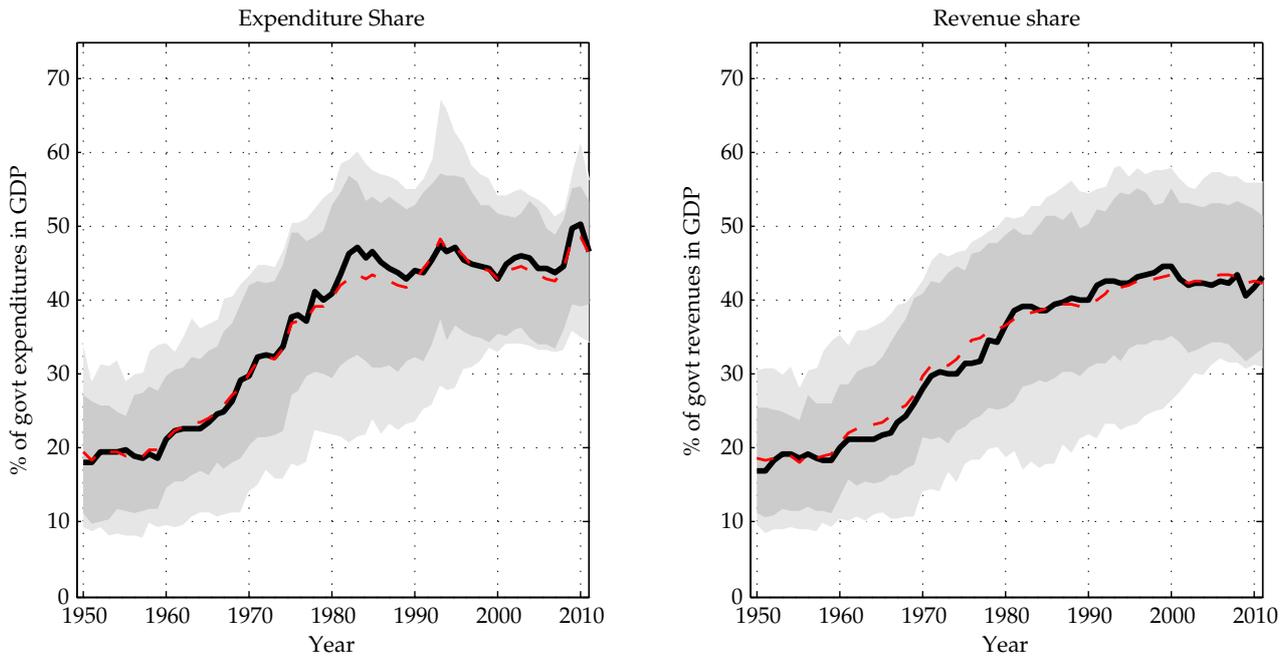
³For instance Backus, Kehoe, and Kydland (1992), Dedola and Leduc (2001), Kollmann (2002), Gali and Monacelli (2005) and Bergin, Shin, and Tchakarov (2007).

⁴See also Calvo and Reinhart (2002), Sutherland (2005) or Devereux, Lane, and Xu (2006).

⁵Mauro, Romeu, Binder, and Zaman (2015) have collected a historical dataset of fiscal variables for a large panel of coun-

timates with the corresponding confidence bounds are computed. The evidence is striking. Both fiscal expenditures and revenues have increased substantially between 1960 and 1980. The statistics reported in Table 1 confirm this evidence. While the size of the public sector was slightly above 20% in the period 1950-70, it experienced a sharp increase in the 70's and 80's, reaching a level of almost 45% in the period 1990-2010.⁶

Figure 1: Development of government size for 22 OECD economies



Notes: Solid black line: Median estimate. Dashed red line: Mean estimate. Dark gray shaded area: 95% confidence interval of median estimate. Light gray shaded area: 68% confidence bands. Source: Mauro, Romeu, Binder, and Zaman (2015).

Table 1: Development of median government size

	<i>Expenditure share</i>			<i>Revenue share</i>		
	1950-70	1970-90	1990-2010	1950-70	1970-90	1990-2010
Median	21.11	41.08	44.86	20.21	36.76	42.48
Minimum	18.09	29.68	43.02	16.90	27.99	39.96
Maximum	29.68	47.13	50.26	27.99	40.36	44.68

Previous theoretical works studying the implications of government size for the business cycle

tries. From the 55 countries in their sample, the evidence reported herein is restricted to the 22 main OECD economies. The data refers to the most comprehensive sector of government for which it was available, i.e., general government consists of central, state and local governments and the social security funds controlled by these units. However, government expenditures *do not* include interest payments.

⁶Similar evidence has been reported by Tanzi and Schuknecht (2000), who document for a smaller selection of developed economies an increase in government size from an average share of about 10% of general government expenditures in GDP in the late 19th century to 45% by the end of the 20th century.

and macroeconomic stability are guided by the empirical evidence of [Gali \(1994\)](#), [Fatás and Mihov \(2001\)](#), [Andrés, Doménech, and Fatas \(2008\)](#) and [Leibrecht and Scharler \(2015\)](#), who report for developed countries a significant negative correlation of aggregate private sector volatility with the size of governments. One strand of literature links this stylized fact to automatic stabilizers and studies the impact of government size on the volatility of output, e.g. in the traditional business cycle literature (see [Gali \(1994\)](#) and [Guo and Harrison \(2006\)](#)) as well as in models incorporating nominal and real rigidities (see [Andrés and Doménech \(2006\)](#) and [Andrés, Doménech, and Fatas \(2008\)](#)). However, these studies have only dealt with closed economies and assumed that the standard technology shock is the sole source of stochastic disturbance. The present article starts by extending this literature to an open-economy setting. A central contribution of this paper is then to provide a normative study of public sector size in relation to the selection of exchange rate regime.

To study this question, a small open economy stochastic general equilibrium framework with nominal rigidities is applied. The core of the model draws on the works of [Gali \(1994\)](#) and [Andrés and Doménech \(2006\)](#), however, differences arise along several dimensions. First, the extension to an open economy framework allows for a quantitative investigation of the link between government size and different degrees of economic openness. Second, the model not only studies the role of a single domestic technology shock but also includes foreign disturbances. These first two contributions to the existing literature are not only crucial to study the welfare properties of different exchange rate regimes, they are also important to capture the so-called compensation hypothesis brought forward by [Rodrik \(1998\)](#). Accordingly, economies which are relatively open to trade tend to have larger governments to reduce the risk from foreign shocks. Related to this and the present work is the finding of [Kamenik and Kumhof \(2014\)](#), who show that net welfare gains of floating exchange rates increase with trade openness. Third, monetary policy is given an active role in shaping the exchange rate policy. This feature is important to gauge the relevance of exchange rate stabilization depending on government size. Finally, the model includes a fiscal rule which stipulates that the government sets taxes as a function of its passed liabilities. This establishes a link between the exchange rate policy and the generation of public sector revenues, hence generating a direct channel to the decision of how the government sets the tax rate.

The concept of government size adopted in this paper follows the related literature and is based on the revenue and expenditure shares of the government. Specifically, a larger government size means a higher steady state government consumption-to-GDP ratio and an equally higher income tax rate. Similar to [Kamenik and Kumhof \(2014\)](#), content to the numerical analysis of exchange rate flexibility is given by evaluating the response of the model economy to shocks under either a fixed or a flexible exchange rate regime and at different degrees of government size. A regime of flexible exchange rates is either defined by a money supply rule or by a welfare maximizing optimal simple interest rate rule, which is very commonly used in practice.⁷ The welfare metric is computed by means of a second-order approximation of the model following the methodology of [Kim, Kim, Schaumburg, and Sims \(2008\)](#). On the one hand, the paper compares the welfare costs of eliminat-

⁷See for instance [Schmitt-Grohé and Uribe \(2007\)](#) or [Bergin, Shin, and Tchakarov \(2007\)](#).

ing the business cycle for different sizes of the public sector. This approach is for instance related to [Kollmann \(2002\)](#), [Kollmann \(2005\)](#) and [Bergin, Shin, and Tchakarov \(2007\)](#). On the other hand, comparable to [Kamenik and Kumhof \(2014\)](#), the change in the benefit of exchange rate flexibility as government size increases is calculated as the incremental welfare gain of flexible over fixed exchange rates.

The main result is that the net welfare costs of pegging the exchange rate monotonically increase with government size. Although increasing the size of government mitigates output variability irrespective of the exchange rate regime in place, the volatility of private consumption is an increasing function of public sector size and crucially affected by the exchange rate regime in place. The intuition for the connection between government size and the exchange rate regime is based on two facts. On the real side, economies with large governments exhibit higher private sector volatility as a result of a composition effect. Everything else equal, private consumption and investment have to absorb more volatility of the shocks, the larger the rigid public sector. Moreover, a large government comes along with a high income tax rate, which has a distorting effect on households' labor supply decision, inducing more volatility in the welfare relevant hours worked. On the nominal side, besides affecting prices, the monetary policy and exchange rate regime in place have an effect on the government's budget constraint and consequently its capacity to adjust the income tax rate. For instance, when the monetary authority conducts a money supply rule with purely floating exchange rates, seigniorage revenues are constant and the government can only pay back its liabilities by generating a primary surplus, i.e. the difference in tax revenues to its consumption expenditures. If instead the central bank credibly pegs the exchange rate, it loses a policy instrument and hence an important adjustment mechanism. This induces per se additional variability into prices, hence affecting negatively the volatility of private consumption. Moreover, to sustain a credible peg, the central bank has to adjust endogenously its money supply, which implies possibly generating seigniorage revenues to the government. This additional revenue in turn alleviates the government budget constraint, allowing the government to hold less liabilities and thus give a more prominent role for counter-cyclical tax adjustments. Consequently, large governments have a destabilizing effect on private sector activity, which is magnified substantially when the central bank decides to prevent the possibility of a nominal exchange rate adjustment to foreign shocks.

The paper further examines how the main results depend upon the specifications of fiscal and monetary policy. When the fiscal authority decides to use lump-sum rather than distortionary taxation as a policy instrument, the level of the income tax no longer twists the labor supply decision such that the volatility of hours worked and consequently aggregate volatility is substantially reduced. Changing the fiscal rule to a spending rather than revenue rule has similar implications. By magnifying the effect of automatic stabilization, the variability in private consumption is diminished, implying lower net welfare gains of floating exchange rates. When the central bank runs a Taylor rule different from the optimal simple rule studied in the benchmark experiment, for instance by targeting domestic inflation only, the qualitative implications of the main results remain robust. Importantly, whenever the stabilization of variability in the nominal exchange rate is included in the policy rule, it

is optimal to attain a weight larger than zero to this objective. In other words, mitigating fluctuations in the nominal exchange rate is welfare superior to a purely floating exchange rate regime. When it comes to model parameters, the Frish elasticity of labor supply takes on an important role: a low value reinforces the destabilizing effect of the income tax rate on the household's labor supply decision, hence increasing the volatility of hours worked. If, on the other hand the labor supply elasticity is large, then hours worked are less responsive to changes in the tax rate and the net welfare gains are lower than in the benchmark. Overall, for any parameter specification studied it is reported that net welfare gains of floating exchange rate regimes over a strict peg increase with the size of government.

The paper is organized as follows. The next section outlines the baseline small open economy model. Section 3 presents the model calibration and the computational details. Focusing on the quantitative properties of government size and the exchange rate regime, Section 4 analyzes welfare, second moments and dynamic responses generated by the proposed model. Sections 5 discusses the robustness of the main results to changes in policies and parametrization. Section 6 concludes.

2 The model

The starting point for the investigation of the welfare consequences of alternative exchange rate arrangements as a function of public sector size is a baseline small open economy.⁸ The domestic economy is small with respect to the rest of the world and consists of three building blocks. First, there is a utility maximizing infinitely lived representative household who can buy internationally traded goods and has access to domestic and foreign bonds. Capital is included in the model to stay close to the related literature examining the effects of government size and automatic stabilizers.⁹ The second building block consists of final goods and intermediate goods producing firms. The final goods sector is perfectly competitive, while there is monopolistic competition in the intermediate goods sector. Intermediate goods producers face nominal rigidities in the form of price adjustment costs and use capital and labor as productive inputs. The public sector constitutes the third building block. In order to finance a certain level of public consumption, the government creates revenues from levying time-varying distortionary income taxes and from seigniorage. The central bank can follow three policies: Either it follows a constant money growth rule, strictly pegs the exchange rate or operates a nominal interest rate rule.

I follow the standard notational convention to indicate foreign variables with a superscripted asterisk and the destination of traded variables with a subscripted H or F , respectively. Lower case letters denote real variables whereas upper case letters denote nominal variables.

2.1 Households

The domestic household derives utility $U\left(c_t, \frac{M_t}{P_t}, l_t\right)$ from a bundle of consumption goods c_t , from holding real money balances $\frac{M_t}{P_t}$ and from enjoying leisure l_t . The total time endowment is normal-

⁸Recent examples of similar models include [Gali and Monacelli \(2005\)](#) (although with complete asset markets), [Kollmann \(2005\)](#), [Bergin, Shin, and Tchakarov \(2007\)](#) and [Divino \(2009\)](#) among many others.

⁹For instance [Andrés and Doménech \(2006\)](#) and [Andrés, Doménech, and Fatas \(2008\)](#).

ized to unity such that the time constraint of the household reads

$$l_t = 1 - n_t, \quad (2.1)$$

with $n_t \in (0, 1)$ standing for hours worked. $U(\cdot)$ is a temporal utility function which is increasing and concave in its three arguments. The representative household maximizes its expected lifetime utility

$$\arg \max_{\mathcal{S}} U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U \left(c_t, \frac{M_t}{P_t}, l_t \right), \quad 0 < \beta < 1,$$

in which \mathbb{E}_0 is the conditional expectations operator in period 0, and β is the discount factor. The household maximizes utility by choosing optimally a sequence of $\mathcal{S} = \left\{ c_t, i_t, \frac{M_t}{P_t}, n_t, B_{F,t}, B_{H,t} \right\}_{t=0}^{\infty}$ subject to the period-by-period budget constraint

$$\begin{aligned} & P_t(c_t + i_t + \Psi_B(S_t B_{F,t})) + B_{H,t} + S_t B_{F,t} + M_t \\ & \leq (1 - \tau_t^D)(W_t n_t + R_t^z k_t) + R_{t-1} B_{H,t-1} + S_t R_{t-1}^* B_{F,t-1} + M_{t-1} + \Pi_t + P_{H,t} \tau_t^L. \end{aligned} \quad (2.2)$$

Note that $B_{H,t}$ is a one-period domestic bond, which cannot be traded internationally and is in zero net supply at the domestic household level. The domestic bond returns a gross nominal rate of interest R_t . $B_{F,t}$ is a traded one-period foreign bond denominated in the foreign currency with an exogenous gross nominal return of R_t^* . It is costly to hold a quantity of foreign assets in the portfolio which is away from some long-run level \bar{B}_F . Following [Schmitt-Grohé and Uribe \(2003\)](#), $\Psi_B(S_t B_{F,t})$ ¹⁰ describes the convex portfolio adjustment cost function and serves to induce stationarity into the foreign debt process and to close the small open economy model.¹¹ M_{t-1} is the amount of money which the household brings into period t and M_t is the end of period money stock of the household. It derives income from selling labor n_t at the nominal wage rate W_t and from renting capital to firms at a rental rate R_t^z . Π_t is the dividend payment the household gets from the domestic competitive firms. It has to pay a time-varying distortionary income tax τ^D and pays (receives) τ_t^L as a lump-sum tax (transfer) to (from) the government.¹² All these variables are denominated in domestic currency, with P_t being the nominal price of the final domestic consumption good. S_t is the nominal exchange rate, specified such that an increase in S_t implies a depreciation of the domestic currency.¹³

The household allocates resources between consumption c_t and investment into physical capital, i_t . The consumption bundle c_t comprises final *tradable* domestic and foreign goods, summarized in a

¹⁰ $\Psi_B'(S_t B_{F,t}) > 0$, $\Psi_B''(S_t B_{F,t}) > 0$, with $\Psi_B(\bar{S} \bar{B}_F) = \Psi_B'(\bar{S} \bar{B}_F) = 0$ and $\Psi_B''(\bar{S} \bar{B}_F) = \psi_B$

¹¹This approach also comes to use in related papers with small open economy models, such as [Devereux, Lane, and Xu \(2006\)](#), [Shi \(2011\)](#) and [Punzi \(2013\)](#). [Schmitt-Grohé and Uribe \(2003\)](#) show that portfolio adjustment costs are one way among others (e.g., endogenous discount rate, debt elastic interest rate, complete asset markets) to get rid of the unit root problem of net foreign assets in small open economy models. Most importantly, all approaches to eliminate this unit root problem deliver virtually identical dynamics at business-cycle frequencies, as measured by unconditional second moments and impulse response functions.

¹²From here on it is referred to τ^L as a lump-sum tax, irrespective of its sign.

¹³The amount of domestic currency per units of foreign currency defines the nominal exchange rate. $\Delta S_t = \frac{S_t}{S_{t-1}}$. When $\Delta S_t > 1$, the domestic currency depreciates, i.e., the domestic household has to pay more for foreign currency in period t than in period $(t - 1)$.

CES aggregation function, formally

$$c_t = \left[(1 - \gamma)^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (2.3)$$

in which the parameter $\eta > 0$ measures the elasticity of substitution between the two goods. The parameter $\gamma \in [0, 1]$ indexes the degree of value the household attributes to the good from the foreign economy. γ can be thought of as a natural measure of openness, which accounts for the degree of home bias. The consumer price index (CPI) is then a weighted average of the price level in the domestic economy and the price level in the foreign economy, given by

$$P_t = \left[(1 - \gamma) P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}. \quad (2.4)$$

$P_{H,t}(P_{F,t})$ is the average price of domestically (foreign) produced consumption goods. The solution to the optimal expenditure allocation problem of the household yields the demand equations for the home and foreign good:

$$c_{H,t} = (1 - \gamma) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} c_t; \quad c_{F,t} = \gamma \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} c_t. \quad (2.5)$$

The law of motion for physical capital is

$$k_{t+1} = (1 - \delta)k_t - \Psi_K(i_t, k_t) + i_t, \quad (2.6)$$

where δ is the depreciation rate and the function $\Psi_K(\cdot) = \psi_K(\cdot)k_t$ denotes the cost of adjusting the capital stock.¹⁴ With equation (2.2) and the necessary transversality condition to prevent the household from engaging in Ponzi schemes, the household's optimization problem is characterized by first order conditions which are standard in the literature.¹⁵

2.2 Private sector

There is imperfect competition in the intermediate goods sector such that intermediate goods producing firms are price setters.¹⁶ In the domestic production sector, we have a competitive firm that aggregates intermediate inputs from monopolistically competitive firms into a final good. Nominal rigidities are introduced by adopting the framework of costly price adjustments in the intermediate goods sector, as proposed by Rotemberg (1982).

Final good firm. The competitive final good firm uses the following constant returns to scale technology:

$$y_t = \left[\int_0^1 y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \quad (2.7)$$

¹⁴Schmitt-Grohé (1998) shows that investment tends to exhibit excess volatility in small open economy models. To avoid this, capital adjustment costs are introduced following Hayashi (1982). The function $\psi_K(\cdot)$ is increasing and concave, satisfying $\psi'_K > 0$, $\psi''_K > 0$, with $\psi_K(\delta) = \psi'_K(\delta) = 0$ and $\psi''_K(\delta) = \psi_K > 0$.

¹⁵The transversality condition is given by $\lim_{t \rightarrow \infty} \beta^t \Omega_{t+1} \Lambda_t = 0$, with $\Omega_t = B_{H,t} + S_t B_{F,t} + M_t$. See A for a detailed list of first order conditions and equilibrium conditions.

¹⁶See for example Chari, Kehoe, and McGrattan (2002).

with $\epsilon > 1$ denoting the constant elasticity of substitution between differentiated intermediate inputs. Demand faced by each individual domestic good, j , is

$$y_t(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}} \right]^{-\epsilon} y_t, \quad (2.8)$$

in which y_t is the total domestic demand for the final good, and $\frac{P_{H,t}(j)}{P_{H,t}}$ is the relative price of each variety with respect to the aggregate domestic price level, $P_{H,t}$, which is given by

$$P_{H,t} = \left[\int_0^1 P_{H,t}(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}. \quad (2.9)$$

Intermediate goods producer. There is a continuum of intermediate goods producing firms in the $(0, 1)$ interval. Each intermediate firm j produces output using capital and labor as productive inputs,

$$y_t(j) = a_t k_t(j)^\alpha n_t(j)^{(1-\alpha)}, \quad (2.10)$$

in which $\alpha \in (0, 1)$ is the capital share. The technology level a_t follows an AR(1)-process with $|\rho_a| < 1$ and $\epsilon_{a,t} \sim \mathcal{N}(0, \sigma_a^2)$ and is identical to all domestic intermediate goods producers. There is perfect competition in the input markets, with firms minimizing their production costs by choosing optimally the amount of labor and capital, taking wages and the rental rate of capital as given. Since firms are identical, they all choose the same amount of private inputs. Real marginal costs are derived from cost minimization such that by aggregating the first order conditions to this problem the demand for labor and capital can be obtained:

$$\frac{W_t}{P_{H,t}} = (1 - \alpha) m c_t \frac{y_t}{n_t}, \quad \frac{R_t^z}{P_{H,t}} = \alpha m c_t \frac{y_t}{k_t}. \quad (2.11)$$

Firms are monopolistically competitive in the intermediate goods market. When the firm decides to change its price, it faces a quadratic price-adjustment cost as proposed by Rotemberg (1982). The following equation gives the real cost function:

$$\Psi_P(\cdot) \equiv \frac{\kappa}{2} \left(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - \bar{\pi}_H \right)^2 y_t, \quad (2.12)$$

in which $\kappa > 0$ determines the degree of nominal price rigidity. Adjustment costs increasing with the size of the price change and with the overall economic activity. There are no costs to adjusting prices when the steady state domestic inflation rate, $\bar{\pi}_H$, prevails.

The intermediate goods producing firm maximizes its expected future discounted real value of profits

$$\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Phi_{t+\tau,t} \frac{\Pi_{t+\tau}(j)}{P_{H,t+\tau}} \right].$$

$\Phi_{t+i,t}$ is the stochastic discount factor given by $\beta^i \left[\frac{U_{c,t+i}}{U_{c,t}} \right]$ and $\frac{\Pi_{t+i}(j)}{P_{H,t+i}}$ are the real value profits of intermediate goods firms. The intermediate goods producing firm maximizes expected future discounted

profits subject to the demand equation for good j , given by equation (2.8). In a symmetric equilibrium, all firms choose the same price $P_{H,t}(j) = P_{H,t}(j') = P_{H,t}$ and also $\frac{P_{H,t}}{P_{H,t-1}} = \pi_{H,t}$, hence

$$\frac{(\epsilon - 1)}{\epsilon} = mc_t - \frac{\kappa}{\epsilon} \left\{ (\pi_{H,t} - \bar{\pi}_H) \pi_{H,t} + \beta \mathbb{E}_t \left[(\pi_{H,t+1} - \bar{\pi}_H) \pi_{H,t+1} \left(\frac{y_{t+1}}{y_t} \right) \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \right] \right\}. \quad (2.13)$$

A first-order linear approximation of equation (2.13) around its non-stochastic steady state yields the standard Phillips curve on domestic producer prices

$$\hat{\pi}_{H,t} = \frac{\epsilon - 1}{\kappa \bar{\pi}_H} \hat{m}c_t + \beta \mathbb{E}_t \hat{\pi}_{H,t+1}. \quad (2.14)$$

Domestic inflation depends upon the price elasticity of demand, ϵ , the level of price adjustment costs, κ , as well as on the adjustment in real marginal costs, $\hat{m}c_t$. Note that in the case of $\kappa \rightarrow 0$, we have fully flexible prices and a constant markup equal to $\frac{\epsilon-1}{\epsilon}$.

2.3 Government

The consolidated government prints money M_t , issues one-period nominal risk-free bonds, $B_{H,t}$, generates tax revenues in the amount of $P_{H,t}\tau_t$, and has expenditures g_t . The period-by-period budget constraint in nominal terms is given by

$$M_t + B_{H,t} + P_{H,t}\tau_t = R_{t-1}B_{H,t-1} + M_{t-1} + P_{H,t}g_t. \quad (2.15)$$

Note that R_t denotes the one-period nominal risk-free interest rate in period t . The amount of government purchases g_t is fully allocated to domestically produced goods and fixed at some level \bar{g} for all time periods.¹⁷ One way how the government collects its revenues is through household taxation, τ_t . The government finances its purchases of goods and services from the private sector through time-varying distortionary income taxes τ_t^D and a lump-sum tax τ_t^L . Total tax revenues are then given by

$$\tau_t = \tau_t^L + \tau_t^D y_t. \quad (2.16)$$

Besides collecting tax revenues, the government also generates revenues from direct receipts of the central bank, denoted by RCB_t . To see this, consider the budget identity for the central bank,

$$RCB_t = M_t - M_{t-1}. \quad (2.17)$$

¹⁷Two comments are in order here: (1) The assumption of 100% home bias in government spending is supported by evidence found in [Trionfetti \(2000\)](#) and [Brülhart and Trionfetti \(2004\)](#), who find in the OECD economies a substantially stronger home bias in government consumption relative to private consumption. This implies on the one hand that government spending is not exposed to adjustments in the terms of trade, i.e., to exchange rate risk (see for instance [Gali and Monacelli \(2008\)](#)). On the other hand, the terms of trade show up in the aggregate resource constraint (Equation 2.31). See Section 4.3.1 for further details. (2) In contrast to the evidence presented in Figure 1, in the present experiment, mainly to keep it tractable, it is not distinguished between the different components of government expenditures. For example [Finn \(1998\)](#), [Quadrini and Trigari \(2007\)](#) or [Gomes \(2010\)](#) study the role of public employment and wages in business cycle models. As it is not the aim of the present paper to investigate the cyclical implications of different measures of government spending, it is abstracted from this differentiation by taking a shortcut and fixing the total amount of public spending at some level \bar{g} .

Equation (2.17) states that the central bank's own liabilities consist of the non-interest bearing monetary base, i.e., the stock of currency held by the household. Changes in the stock of currency represents seigniorage, the revenue from money creation.

Real government liabilities outstanding at the end of period $t - 1$ in units of period $t - 1$ goods are defined as $l_{t-1} \equiv (M_{t-1} + R_{t-1}B_{H,t-1}) / P_{t-1}$, similarly to [Schmitt-Grohé and Uribe \(2007\)](#). Real money balances in circulation are equal to $m_t \equiv M_t / P_t$. Taken together, the government budget constraint can be written as

$$l_t = \frac{R_t}{\pi_t} l_{t-1} - m_t(R_t - 1) + R_t p_{H,t}(\bar{g} - \tau_t), \quad (2.18)$$

with $\pi_t = P_t / P_{t-1}$ being the consumer price inflation.

Monetary and fiscal policies. The model experiments will consider three alternative simple monetary policy rules. In the first specification, the money supply is exogenously fixed at some constant rate, such that the money supply evolves according to

$$M_t = M_{t-1}. \quad (2.19)$$

For later comparisons this rule will be used as a benchmark, since it implies no endogenous response of policy to economic shocks or circumstances. It further stands for a *fully flexible exchange rate* arrangement. The second rule is characterized by a *strict exchange rate peg*. In that case, the central bank fully commits to eliminate fluctuations in the nominal exchange rate,

$$S_t = S_{t-1}. \quad (2.20)$$

The third monetary policy rule is a Taylor-type interest rate rule with full commitment based on [Taylor \(1993\)](#).¹⁸ The central bank's target for the nominal interest rate, \bar{R}_t , is described by the following equation:

$$\bar{R}_t = \bar{R} \left(\frac{P_t}{P_{t-1}} \right)^{\gamma_\pi} \left(\frac{y_t}{\bar{y}} \right)^{\gamma_y} \left(\frac{S_t}{S_{t-1}} \right)^{\frac{\gamma_e}{1-\gamma_e}}. \quad (2.21)$$

In a setting with *active* monetary policy, the central bank adjusts the nominal interest rate by putting a weight to current inflation ($\gamma_\pi \geq 1$), deviations from steady state output ($\gamma_y \geq 0$), and to changes in the nominal exchange rate ($\gamma_e \in [0, 1)$). When $\gamma_e = 0$, a purely floating exchange rate regime is implemented. When $\gamma_e \in (0, 1)$, the central bank adjust the interest rate to changes in the exchange rate, which is called a *managed float*.¹⁹ In the extreme case of $\gamma_e \rightarrow 1$, the regime represents a strict peg. In the steady state, the target interest rate equals \bar{R} . Following [Monacelli \(2004\)](#), the monetary authority has the desire to smooth changes in the nominal interest rate at a rate ρ_R such that the determination of the actual short-term nominal interest rate, R_t , can be described as follows,

$$R_t = (\bar{R}_t)^{1-\rho_R} (R_{t-1})^{\rho_R}. \quad (2.22)$$

¹⁸The rule has found wide application in the open economy context, for example in [Kollmann \(2002\)](#), [Monacelli \(2004\)](#), [Devereux, Lane, and Xu \(2006\)](#), or [Bergin, Shin, and Tchakarov \(2007\)](#).

¹⁹See [Calvo and Reinhart \(2002\)](#) who show that interest rate policies replace interventions in the foreign exchange market as a device for smoothing exchange rates.

With this rule, the central bank sets a long-run target for CPI inflation, output and the nominal exchange rate, and it adjusts the nominal interest rate as a feedback on short-run deviations from this target:

$$R_t = \left[\left(\frac{P_t}{P_{t-1}} \right)^{\gamma_\pi} \left(\frac{y_t}{\bar{y}} \right)^{\gamma_y} \left(\frac{S_t}{S_{t-1}} \right)^{\frac{\gamma_e}{1-\gamma_e}} \bar{R} \right]^{1-\rho_R} (R_{t-1})^{\rho_R}. \quad (2.23)$$

Provided that monetary policy is active and γ_π is above a certain threshold value, fiscal policy must be designed to satisfy the present value budget constraint of the government for any price level in order to obtain a unique monetary equilibrium (Leeper, 1991). This requirement can be made operational by the formulation of simple fiscal feedback rules such that either taxes or public expenditures respond sufficiently to the level of liabilities (domestic debt or cash holdings). In the benchmark case, a similar fiscal rule to the one suggested by Schmitt-Grohé and Uribe (2007) is adopted:

$$\frac{\tau_t}{\bar{\tau}} = \left(\frac{l_{t-1}}{\bar{l}} \right)^{\gamma_1}, \quad (2.24)$$

where $\bar{\tau}$ and \bar{l} are the steady state values of tax revenues and liabilities respectively, and γ_1 is a parameter which determines how the government sets tax revenues in period t in response to the real value of total government liabilities in $t - 1$. It is assumed that γ_1 is set in the interval $(0, 2/\bar{\pi})$, such that fiscal policy is passive in the sense of Leeper (1991). This assumption is justified by the finding of Schmitt-Grohé and Uribe (2007), who show that optimal fiscal policy is passive. It is *a priori* indeterminate which tax rate should be adjusted when government revenues change. Here, a purely positive approach to the problem is adopted. Following Haavelmo's rule, two policies emerge with this fiscal specification: First, the government only adjusts lump-sum taxes, setting $\tau_t^D = \bar{\tau}^D$ at all times; and second, only distortionary taxes are allowed to vary, with $\tau_t^L = \bar{\tau}^L$. In the following, the focus will be laid on the latter case as a benchmark experiment.

2.4 Foreign economy

The foreign economy is large relative to the home country, hence foreign consumption equals foreign output and the distinction between foreign consumer price inflation and foreign CPI inflation is unnecessary.²⁰ It is assumed that the law of one price holds, which implies that the foreign goods price paid by domestic households equals the foreign currency price of foreign-produced goods, $P_{F,t} = S_t P_t^*$. If there is home bias in consumption, with $\gamma < 1$, deviations from purchasing power parity can arise. To this end, the real exchange rate is defined as $Q_t \equiv S_t P_t^* / P_t$. Foreign and domestic agents share the same preferences, which implies that the consumption Euler equation determines the foreign interest rate, given by²¹

$$y_t^{*-\sigma} = \beta R_t^* \mathbb{E}_t \left[\frac{y_{t+1}^{*-\sigma}}{\pi_{t+1}^*} \right]. \quad (2.25)$$

²⁰See among many others Clarida, Gali, and Gertler (2001), Gali and Monacelli (2005), Faia and Monacelli (2008) or De Paoli (2009).

²¹See for example Divino (2009), Faia and Iliopoulos (2011) and chapter 6.5 in Walsh (2010) for this approach.

The foreign prices P_t^* and output y_t^* are represented by exogenous and independent AR(1)-processes,

$$\log(x_t^*) = \rho_x \log(x_{t-1}^*) + (1 - \rho_x)\bar{x} + \epsilon_{x,t}^*, \quad \text{for } x = y, \pi, \quad (2.26)$$

with $|\rho_x| < 1$ and $\epsilon_{x,t} \sim \mathcal{N}(0, \sigma_x^2)$ and $\pi_t^* = P_t^*/P_{t-1}^*$. As the countries are symmetric in their consumption preferences, the demand of the foreign economy for the domestically produced good (the exports of the domestic economy) can be characterized by the following expression:

$$c_{H,t}^* = \gamma \left(\frac{P_{H,t}}{S_t P_t^*} \right)^{-\eta} y_t^*. \quad (2.27)$$

2.5 Equilibrium

In the equilibrium, all domestic households are identical and we have zero net-supply of domestic bonds, $B_{H,t} = 0$. The aggregate budget constraint of the domestic residents gives the evolution of foreign debt, which evolves according to

$$S_t B_{F,t} = R_{t-1}^* S_t B_{F,t-1} + NX_t, \quad (2.28)$$

with the net exports NX_t being equal to exports minus imports,

$$NX_t = P_{H,t} c_{H,t}^* - P_{F,t} c_{F,t}. \quad (2.29)$$

Aggregate employment is a continuum of the labor types, clearing the labor market with the following condition:

$$n_t = \int_0^1 n_t(j) dj. \quad (2.30)$$

Finally, goods market clearing in the domestic economy yields the aggregate resource constraint:

$$P_t(c_t + i_t) + P_{H,t} g_t + NX_t + P_t \frac{\phi_B}{2} (S_t B_{F,t} - \bar{B}_F)^2 + P_{H,t} \frac{\kappa}{2} \left(\frac{P_{H,t}}{P_{H,t-1}} - \bar{\pi}_H \right)^2 y_t = P_{H,t} y_t. \quad (2.31)$$

The competitive general equilibrium of the present model is defined as follows:²²

Definition. Given the sequence of exogenous processes $\mathcal{Z}_{t=0}^\infty = \{a_t, \pi_t^*, y_t^*\}_{t=0}^\infty$ an equilibrium allocation of this economy is a sequence of prices $\mathcal{P}_{t=0}^\infty = \{P_t, P_{H,t}, P_{F,t}, P_t^*, S_t, R_t, R_t^*, W_t, R_t^z\}_{t=0}^\infty$, and quantities $\mathcal{M}_{t=0}^\infty = \{\Lambda_t, q_t, y_t, c_t, i_t, k_t, n_t, M_t, B_{F,t}, B_{H,t}, mc_t, c_{H,t}, c_{F,t}, c_{H,t}^*, g_t, \tau_t, \tau_t^L, \tau_t^D, l_t, NX_t\}_{t=0}^\infty$ satisfying the following conditions: (i) the household's allocation solves its optimization problem; (ii) the prices of intermediate goods producers solve their maximization problem; (iii) the final goods producer's allocation solves its expenditure minimization problem; (iv) the market-clearing conditions hold; (v) the government chooses a fiscal and monetary policy.

The remaining part of the paper presents first the solution method and parametrization of the given model and then turns to its quantitative implications.

²²Appendix A lists the complete set of model equations.

3 Solution method, model parametrization and welfare

The nonlinear stochastic rational expectations model is solved numerically to a second-order approximation.²³ Following Kim and Kim (2003), a first-order approximation based on linear solution methods may lead to highly misleading welfare comparisons, since the interaction of nonlinearities and uncertainty is ignored. Instead, a second-order approximation to the full set of model equations picks up the effects of variability on the means of consumption and leisure. For example, households may engage in precautionary savings which affects mean consumption, or firms may hedge against exchange rate variability by setting higher prices and lowering mean production (Bergin, Shin, and Tchakarov, 2007).

Alternative approaches to welfare evaluation include the linear-quadratic approach developed by Benigno and Woodford (2012), where welfare and the policymaker's objective function can be precisely determined from a second-order approximation to household's utility.²⁴ This approach delivers an analytical representation of the policy problem. In contrast, given the absence of a closed-form solution, the methodology adopted in this paper is based on perturbation methods and delivers a numerical evaluation of the optimal policy problem.²⁵

3.1 Model parametrization

The period utility function is separable in aggregate consumption, real money balances and in labor, following Chari, Kehoe, and McGrattan (2002) it takes the functional form:

$$U(\cdot) = \frac{c_t^{1-\sigma} - 1}{1-\sigma} + \frac{\vartheta}{1-b} \left(\frac{M_t}{P_t} \right)^{1-b} - \chi \frac{n_t^{1+v}}{1+v}, \quad 0 < v, b \quad 0 \leq \sigma, \chi, \vartheta.$$

One important feature of this type of utility function is to cut down the level effect of employment which would arise if consumption and leisure were nonseparable, so that we can focus only on the elasticities.²⁶ The deep structural parameters are taken from the literature (if not stated otherwise), and the time unit is chosen to be one quarter.

For the parametrization of the model, the paper follows much of the suggestions of the business cycle literature, with a particular focus on a typical small open economy such as Canada.²⁷ Table 2 gives a summary of the calibrated parameter values.²⁸ The discount factor β is set such that the

²³Consider Schmitt-Grohé and Uribe (2004) and Kim, Kim, Schaumburg, and Sims (2008) for a detailed explanation of the methodology.

²⁴See also for example Sutherland (2002).

²⁵See also Collard and Juillard (2001). For the simulation of the model I use the DYNARE implementation for Matlab (<http://www.dynare.org>).

²⁶See Guo and Harrison (2006) for a discussion on the sensitivity of the results presented in Gali (1994). The stabilizing effect of government size on output volatility depends primarily on how hours enter the household's period utility function. The utility function assumed in this paper is a further generalization of U_2 in Guo and Harrison (2006), who assume $\sigma = 1$.

²⁷See for example Devereux, Lane, and Xu (2006) and Faia and Iliopoulos (2011), as well as Backus, Kehoe, and Kydland (1992), Chari, Kehoe, and McGrattan (2002) and Dellas (2006).

²⁸As it is not the aim of the paper to maximize the fit of the model to empirical regularities, the parameter values are to be viewed as suggestive.

annual steady state world interest rate is 4%. The intertemporal elasticity of substitution in consumption, σ , and real money balances, b , are equalized to the inverse labor supply elasticity, and their value is set to $\sigma = b = \nu = 2$.²⁹ Real money balances are introduced to the household's utility function to generate a money demand equation. Following [Kollmann \(2005\)](#), the weight of money balances, ϑ , is set at a very small number, so that money is (essentially) neutral under flexible prices. Moreover, this calibration allows us to focus only on the volatility of consumption and labor for the welfare analysis. The weight of labor in the utility function, χ , matches the amount of hours the households devote to work. It is assumed that one third of the total time endowment is for work, i.e., $\bar{n} = 1/3$. In the benchmark parametrization in [Table 2](#), χ then equals 31.1.

Table 2: Benchmark parameters

Parameter	Value	Description
<i>Structural Parameters</i>		
β	$1.04^{-0.25}$	Subjective discount factor (quarterly)
σ	2	Risk aversion
ν	2	Inverse Frish labor supply elasticity
ϑ	$1 * 10^{-6}$	Utility weight on money balances
χ	31.1	Utility weight on leisure
b	2	Intertemporal elasticity of substitution of money balances
η	1.5	Elasticity of substitution between h and f Consumption
ψ_{B_F}	0.0019	Portfolio adjustment cost
γ	0.4	Share of foreign good in the consumption basket
ϵ	8	Elasticity of substitution between differentiated goods
κ	50	Price adjustment cost parameter
δ	0.025	Depreciation rate
α	0.36	Capital share
ψ_K	15	Capital adjustment cost
<i>Government size</i>		
s_g	[0.2, 0.4, 0.6]	Output share of public expenditures
τ^D	[0.2, 0.4, 0.6]	Distortionary taxes
<i>Steady State values</i>		
\bar{n}	1/3	Steady state hours worked
$\bar{\pi}$	1	Steady state inflation
<i>Exogenous Processes</i>		
$\rho_a, \sigma_{\epsilon^a}$	0.9571, 0.0074	Domestic technology shock
$\rho_y^*, \sigma_{\epsilon_y^*}$	0.9911, 0.0086	Foreign output shock
$\rho_{\pi^*}, \sigma_{\epsilon_{\pi^*}}$	0.8777, 0.0028	Foreign inflation shock

The elasticity of substitution between domestic and foreign goods has been discussed extensively and studies have estimated quite a range for this parameter. Traditionally, the business cycle literature has assumed an elasticity of 1.5, while empirical research has found values for high frequency data ranging from 0.2 to 3.5.³⁰ The benchmark model relies on the commonly used value and sets $\eta = 1.5$, but sensitivity analysis for this and other parameters will be carried out in [Section 5](#). As in [Gali and Monacelli \(2005\)](#), the degree of openness γ equals 0.4. This value corresponds to the

²⁹Changing the values of σ and b does not change the qualitative implications of the main result presented in [Table 3](#). By contrast, the labor supply elasticity plays a crucial role for the results, as will be discussed in more detail in [Section 5](#).

³⁰See for example [Backus, Kehoe, and Kydland \(1992\)](#), [Clarida, Gali, and Gertler \(2001\)](#) and [Collard and Dellas \(2002\)](#) for theoretical contributions and [Shiells, Stern, and Deardorff \(1986\)](#) for an empirical investigation.

Canadian share of imports in GDP, which amounts to roughly 40%. Following [Kollmann \(2002\)](#), the portfolio adjustment cost function reads $\Psi_B(S_t B_{F,t}) = \frac{\psi_B}{2} S_t (B_{F,t} - \bar{B}_F)^2$ and the parameter on portfolio adjustment costs is set to $\psi_{B_F} = 0.0019$.³¹

The elasticity of substitution among the different varieties of goods in the domestic economy, ϵ , is 8, which implies a steady state markup of 15%, a value also used in [Faia and Iliopoulos \(2011\)](#). The parameter governing the cost of price adjustment, κ , is set to be in line with the dynamics of the standard Calvo price adjustment process. As [Keen and Wang \(2007\)](#) show, if ϵ is equal to 8 and assuming a price adjustment on average every 4 quarters, then κ is around 50. Following [Bergin, Shin, and Tchakarov \(2007\)](#), the depreciation rate, $\delta = 0.025$ and the capital share in the production function is $\alpha = 0.36$. The capital adjustment cost function is standard in the literature and reads $\Psi_K(i_t, k_t) = \frac{\psi_K}{2} \left(\frac{i_t}{k_t} - \delta \right)^2 k_t$. The capital adjustment cost parameter, $\psi_K = 15$, is taken from [Kollmann \(2002\)](#).

Government size. In line with [Gali \(1994\)](#), [Andrés and Doménech \(2006\)](#) and [Andrés, Doménech, and Fatas \(2008\)](#), two specific measures of government size are considered. On the expenditure side, government size is characterized by the share of public consumption expenditures in total GDP, denoted by s_g . The revenue side measures government size with the amount of distortionary income taxes being levied, τ^D . Following the evidence reported in [Table 1](#), the average share of government spending in GDP, s_g , is set to 0.4 for the *benchmark* experiment. The income tax rate equals the share of public spending, i.e. $\tau^D = s_g = 0.40$. This value represents approximately the median of the expenditure and revenue share found in the data between 1970 and 2010. A *small government* is defined to have a consumption share and level of distortionary taxes of 20%, which is half of the benchmark and corresponds approximately to the data estimates of 1950-70 reported in [Table 1](#). A *large government* devotes 60% of GDP to government consumption and levies an income tax of 60%, which is in correspondence with the maximum government size found in the data between 1990-2010. The level of lump-sum taxes (transfers) $\tau^L = 0$ in the benchmark specification and γ_1 is set to 0.25 following [Moldovan \(2010\)](#).

Steady state and stochastic components. For the benchmark economy, inflation is zero in the steady state, i.e., $\bar{\pi} = 1$, which leads to $\bar{P} = \bar{P}_H = \bar{P}_F = \bar{P}^* = \bar{\pi} = \bar{\pi}^* = \bar{\pi}_H = r\bar{r} = \bar{\mu} = 1$ and $R = R^* = \frac{\bar{\pi}}{\beta}$.³²

The stochastic components of the model are calibrated to the Canadian (Home) and the US (Foreign) economies. The quarterly data series cover a sample period from 1960:1–2012:4. An AR(1)-process of linearly detrended (log) labor productivity in Canada fits the exogenous process of productivity, yielding the following estimates (with standard error given in parentheses):³³

$$a_t = \underset{(0.0165)}{0.9569} a_{t-1} + \epsilon_{a,t}, \quad \sigma_{\epsilon^a} = 0.0074. \quad (3.1)$$

³¹I have tested the underlying model for different values of these parameters. [Schmitt-Grohé and Uribe \(2003\)](#) use a value of 0.0007 for ψ_{B_F} . Using this higher value would not affect the key results in [Table 3](#). Also, changing the parameter of openness to a value of 0.1, as for example used in [Chari, Kehoe, and McGrattan \(2002\)](#) does not have any qualitative implications for the results.

³²Mostly for practical reasons it has been common in the New Keynesian literature to assume a zero-inflation steady state. Notable exceptions are for example [King and Wolman \(1996\)](#), [Chari, Kehoe, and McGrattan \(2002\)](#), [Ascari \(2004\)](#) and [Ascari and Ropele \(2007\)](#).

³³I have estimated the three exogenous processes also with 4 lags. Qualitatively, the results remain unaffected.

In order to calibrate the sources of stochastic volatility in the rest of the world, quarterly data on linearly detrended US (log-) output and the demeaned log-difference of the US GDP deflator are used. Estimation yields the following results:

$$y_t^* = \underset{(0.0129)}{0.9911} y_{t-1}^* + \epsilon_{y^*,t}, \quad \sigma_{\epsilon_{y^*}} = 0.0086 \quad (3.2)$$

$$\pi_t^* = \underset{(0.0332)}{0.8777} \pi_{t-1}^* + \epsilon_{\pi^*,t}, \quad \sigma_{\epsilon_{\pi^*}} = 0.0028. \quad (3.3)$$

3.2 Welfare measure

Following the literature, a second-order Taylor expansion of the utility function of a representative household around the deterministic steady state, indicated here by overbars, is computed. Home welfare is defined as³⁴

$$\mathcal{W}_{0,t} \equiv \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t, n_t) \right\}, \quad (3.4)$$

or in recursive form

$$\mathcal{W}_{0,t} = U(c_t, n_t) + \beta \mathcal{W}_{0,t+1}, \quad (3.5)$$

in which $U(c_t, n_t)$ denotes the household's period instantaneous utility neglecting the holding of real money balances.³⁵

The exchange rate arrangements are compared based on a compensating measure given by the fraction Θ of household consumption that would be needed to equate conditional welfare $\mathcal{W}_{0,t}^{Rule}$ under the studied exchange rate policy (money supply or Taylor rule) to the level of welfare $\mathcal{W}_{0,t}^{Peg}$ implied by the strict exchange rate peg. Hence, Θ should satisfy the following expression:

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t U((1 + \Theta)c_t, n_t) \right\} = \mathcal{W}_{0,t}^{Peg}. \quad (3.6)$$

With the specification of utility given in Section 3.1, one can solve for Θ and obtain:

$$\Theta = \left\{ \left(\mathcal{W}_{0,t}^{Peg} - \mathcal{W}_{0,t}^{Rule} \right) (1 - \beta)(1 - \sigma) + 1 \right\}^{\frac{1}{1-\sigma}} - 1. \quad (3.7)$$

Note that a value of $\Theta < 0$ stands for a welfare loss of pegging the exchange rate, i.e., the household would have to be paid the fraction Θ (% of consumption) to move from a chosen monetary policy regime to a strict peg. To solve for the reaction parameters $(\rho_R, \gamma_\pi, \gamma_y, \gamma_e)$ in the policy rule presented in equation (2.21), the contingent plans for consumption and hours of work associated with that policy must yield the highest level of unconditional lifetime utility in the home economy (Schmitt-Grohé and Uribe, 2007).

³⁴The chosen welfare metric is based on *conditional* expected discounted utility of the representative household. This takes into account the transition dynamics from the deterministic steady state (the initial condition of the model) to the different stochastic steady states implied by the alternative monetary policy rules. See for example Faia and Monacelli (2007) or Schmitt-Grohé and Uribe (2007).

³⁵In principle, real money balances are in the utility function of the household to generate a demand for money. Following Dellas (2006), the utility weight on money is parametrized such to be basically useless. Therefore, it is also abstracted from reporting the variance of real money balances in Section 4.2 as they do not matter in size for the welfare calculation.

4 Quantifying the effect of government size and the exchange rate regime

This section first shows the welfare results arising from a change in monetary policy and the exchange rate arrangement as a function of public sector size. It explains the results by analyzing the effect of government size and the exchange rate regime on business cycle volatility and model dynamics. The sources of uncertainty driving the business cycle are the domestic productivity shock and the two foreign shocks to output and price inflation.

4.1 Welfare

Table 3 summarizes the main results of the paper. The *rate of change* of the net welfare gains from exchange rate flexibility increase with public sector size. For both exchange rate arrangements considered in the benchmark experiments, increasing government size yields higher welfare costs of implementing a strict exchange rate peg. When the size of the public sector amounts to 20% of GDP, the welfare gains of flexible exchange rates are similar both under fully flexible and managed floating exchange rates. However, when government size increases, the managed floating exchange rate regime exhibits lower welfare costs than the purely floating arrangement.

Table 3: Welfare costs of implementing strict peg

Exchange rate policy ⁽ⁱ⁾	Government size ⁽ⁱⁱ⁾		
	20%	40%	60%
Fully flexible ⁽ⁱⁱⁱ⁾	-2.42	-3.46	-6.97
Managed float ^(iv)	-2.48	-3.65	-7.78

Note: (i) Welfare costs are stated in per-cent of steady state consumption. (ii) $s_g = \tau^D$. (iii) The fully flexible exchange rate regime is characterized by a money supply rule as specified in equation 2.19. (iv) The managed float is characterized by an optimal simple Taylor rule given by equation 2.21.

To gain intuition on these results, the different exchange rate policies can be compared by computing the welfare gains ϑ^{Policy} of a particular exchange rate arrangement expressed by the percentage change in permanent consumption relative to the deterministic steady state such that the representative household is indifferent between being in a particular exchange rate regime and the deterministic steady state of the economy.³⁶ Formally,

$$\mathcal{W}_{0,t}^{Policy} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{Policy}, n_t^{Policy}) = \sum_{t=0}^{\infty} \beta^t U((1 + \vartheta^{Policy})\bar{c}, \bar{n}). \quad (4.1)$$

The second-order expansion of the period utility functions is given by

$$\mathbb{E}[U(c_t, n_t)] = \bar{U} + \bar{c}^{1-\sigma} \left(\mathbb{E}[\hat{c}_t] - \frac{1}{2}\sigma \text{Var}[\hat{c}_t] \right) - \chi \bar{n}^{1+\nu} \left(\mathbb{E}[\hat{n}_t] + \frac{1}{2}\nu \text{Var}[\hat{n}_t] \right), \quad (4.2)$$

³⁶Note that when $\vartheta^{Policy} < 0$ it is a welfare *cost* of fluctuations. Compare Lucas (1987, 2003) for a description on the evaluation of the welfare costs of business cycles.

then, solving equation 4.1 for ϑ^{Policy} yields

$$\vartheta^{Policy} = \left[1 + (1 - \sigma) \left(\mathbb{E}[\hat{c}_t] - \frac{1}{2}\sigma \text{Var}[\hat{c}_t] - \chi \frac{\bar{n}^{1+\nu}}{\bar{c}^{1-\sigma}} \left(\mathbb{E}[\hat{n}_t] + \frac{1}{2}\nu \text{Var}[\hat{n}_t] \right) \right) \right]^{\frac{1}{1-\sigma}} - 1. \quad (4.3)$$

Similar to Kollmann (2002), Bergin, Shin, and Tchakarov (2007) or Evers (2012), the welfare metric ϑ^{Policy} can be decomposed into its mean and variance components, ϑ_M and ϑ_V , where $(1 + \vartheta^{Policy}) = (1 + \vartheta_M)(1 + \vartheta_V)$. Similarly, these two components can be further decomposed into the components corresponding to consumption and hours worked.

Table 4 summarizes the results arising from this exercise. The first row reports the value of the unconditional expected lifetime utility. The second row shows the associated overall welfare costs of eliminating the business cycles for the three monetary policy rules specified in Section 2.3. These costs are disentangled into their mean and variance components and further into the respective contributions attributed to consumption and hours worked.³⁷

Table 4: Welfare comparisons of different exchange rate arrangements

Statistic ⁽ⁱ⁾	Fully flexible			Strict peg			Managed float		
	0.2	0.4	0.6	0.2	0.4	0.6	0.2 ⁽¹⁾	0.4 ⁽²⁾	0.6 ⁽³⁾
Government size ⁽ⁱⁱ⁾									
Expected utility	-100.27	-181.51	-353.77	-102.89	-185.39	-362.42	-100.35	-181.72	-354.75
Welfare gain ϑ^{Policy}	-1.72	-2.98	-7.03	-8.95	-11.29	-22.23	-1.90	-1.91	-2.00
Mean contribution ϑ_M	-0.18	-0.28	-0.46	-0.08	0.04	0.35	-0.23	-0.22	-0.21
Consumption	-0.15	-0.21	-0.34	0.19	0.30	0.57	0.00	0.01	0.02
Hours worked	-0.04	-0.06	-0.12	-0.27	-0.26	-0.22	-0.23	-0.23	-0.23
Variance contribution ϑ_V	-1.54	-2.70	-6.58	-8.87	-11.33	-22.57	-1.67	-1.69	-1.79
Consumption	-1.25	-2.27	-5.78	-2.85	-5.94	-17.90	-0.34	-0.38	-0.45
Hours worked	-0.29	-0.43	-0.81	-6.06	-5.46	-4.84	-1.33	-1.31	-1.33

Note: (i) Welfare costs are stated in per-mil of steady state consumption. (ii) $s_g = \tau^D$. (1) $\rho_R = 0.12, \gamma_y = 0.23, \gamma_\pi = 1.14, \gamma_e = 0.02$. (2) $\rho_R = 0, \gamma_y = 4.98, \gamma_\pi = 2.24, \gamma_e = 0.62$. (3) $\rho_R = 0, \gamma_y = 4.99, \gamma_\pi = 2.27, \gamma_e = 0.63$.

Four essential points emerge: *First*, the managed floating regime characterized by the optimal simple rule yields lower welfare losses than both the fully flexible regime and the exchange rate peg when government size is large. For a small size of the public sector, the fully flexible exchange rate regime (the money supply rule), exhibits lower welfare costs than the other arrangements. For instance, when government size takes on its benchmark value of 40% and the central bank follows the managed floating interest rate rule, the welfare cost of households amounts to 1.91 per mil of their permanent consumption stream. Under a peg these costs are 11.29 per mil and under a money supply rule approximately 3 per mil.

Second, the difference in welfare gains becomes wider the larger the size of the public sector. When the public sector is small, i.e., amounts to 20% of GDP, the optimal simple rule exhibits only slightly higher welfare costs than the money supply rule (-1.90 vs. -1.72), but when government size is large, the welfare costs of implementing such a rule are more than three times those of the

³⁷The exchange rate policies outlined in Section 2.3 give rise to the same non-stochastic steady state.

optimal rule (-2.00 vs -7.03). Under all sizes of the public sector the exchange rate peg is welfare-inferior to a monetary regime with floating exchange rates. Relative to the optimal rule, the costs of implementing a peg are more than four times as large when government size is small (-1.90 vs. -8.95) and exceed a factor of eleven times larger when the public sector has a size of 60% (-2.00 vs. -22.23).

Third, the estimated reaction parameters of the optimal simple rule depend substantially on the size of government. When the government is small, the monetary authority responds to inflation with a coefficient of $\gamma_\pi = 1.14$, when the government is large, this coefficient amounts to 2.27. Also output stabilization gains importance with increasing government size. The interest-rate-smoothing parameter varies between 0 and 0.12, which are low values compared with the existing literature. Section 5.2 will discuss in detail the role of the monetary policy rule and the robustness of these findings. The coefficient on stabilizing fluctuations in the change of the nominal exchange rate, γ_e , is found to increase sharply with government size. Consistent with the findings of Laxton and Pesenti (2003), the exchange rate is only of minor importance when government size is small. Importantly however, stabilizing the exchange rate gains importance as soon as the size of government gets large.

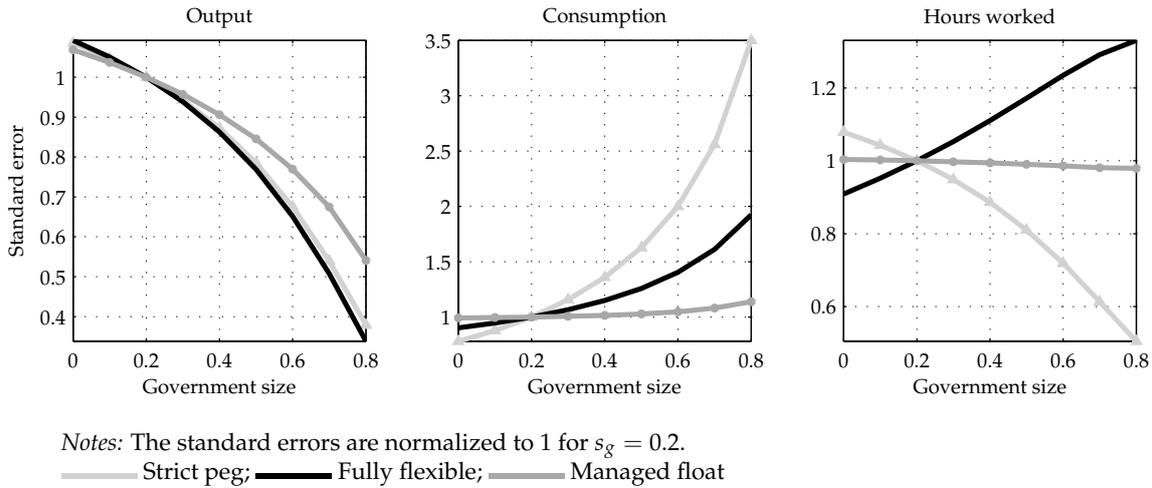
Fourth, it is mainly the variance contribution which matters for the welfare results. The mean effect in the welfare cost measure is negligibly small, which implies that the reported welfare properties are fundamentally related to variations in consumption and hours worked. For all model specifications, the variance components are increasing in government size. Under the fully floating regime and the exchange rate peg, the variance of consumption accounts for a larger share than the one of hours worked. This is reversed, when the optimal rule is implemented. Related to the evidence reported in Baxter and Stockman (1989), it is evident that both the variance of consumption and that of hours worked are substantially larger under pegged exchange rates.

In summary, welfare costs of changing the exchange rate regime from flexible to fixed increase with government size. As the steady state is the same across exchange rate policies, this result has to come from the implied volatility of hours and consumption. This volatility is the result of the propagation of endogenous variables to the various shocks. To gain a deeper understanding of the main results, it is instructive to study how the size of the public sector and the selection of the exchange rate regime affect the volatility and dynamics of selected variables in the presence of the three exogenous driving forces. For this purpose, the paper first analyzes the volatility of output and the welfare-relevant variables, i.e., consumption and hours worked, for different calibrations of the public sector and the different monetary policies under consideration, while holding constant the remaining parameters of the economy.

4.2 Volatility

Figure 2 reports separately the volatility of output, consumption and hours worked for either a fixed exchange rate regime (light grey), the money supply rule with flexible exchange rates (solid black) or the optimal simple rule with a managed float (dark grey) for different sizes of the public sector. Note that the standard errors have been normalized to unity at $s_g = 0.2$. For all specifications it is assumed that the size of public expenditures equals the size of public revenues, i.e., $s_g = \tau^D$.

Figure 2: Volatility of output, consumption and hours for different sizes of government



Focusing on the results for output (i.e., the first column in Figure 2) the results suggest that output volatility is negatively linked to public sector size. Consistent with the findings of Gali (1994), Guo and Harrison (2006) and Andrés, Doménech, and Fatas (2008), output volatility is highest when the government is small and decreases with increasing government size. Here, the paper adds to their results by showing the importance of the monetary policy and exchange rate regime in place. For a government size below 20%, the exchange rate peg exhibits lower output volatility than the other two regimes, although the difference is small (around 0.5 percent). However, when the size of the public sector gets large, we observe that an exchange rate peg exerts a less stabilizing effect on output volatility. Moreover, the difference in volatility increases with government size. When government size reaches 80%, the standard deviation of output is 4.3 percent lower under a money supply and even 18.9 percent when the optimal simple rule is implemented.

Focusing on consumption (second column in Figure 2), the figure shows that consumption volatility monotonically increases with government size, but the rate of increase depends strongly on the monetary policy in place. Consumption volatility increases only slightly when the optimal rule is in place. For instance, when government size rises from 20% to 60%, the standard deviation increases by three percent. For low shares of government spending and tax revenues, the money supply rule and exchange rate peg exhibit lower volatility than the optimal rule. Yet, as government size increases, the difference in the standard deviation of consumption gets increasingly large, especially under the pegged exchange rate regime. In comparison to the optimal rule, when government size amounts to 60%, consumption volatility is about 1.5 times larger under a money supply rule and almost 2.5 times larger under an exchange rate peg.

The third column reports the standard deviation of hours worked for different sizes of the public sector. Evidently, there is substantial variation across monetary policies. We first observe the stabilizing role of government size under floating exchange rates. Under both the money supply and the optimal rule, the standard deviation of hours worked monotonically decreases with government size. On the contrary, when the exchange rate is pegged, volatility of hours worked is an increasing

function of public sector size.

Table 5: Variance decomposition

		Fully flexible			Strict peg			Managed float		
		a_t	y_t^*	π_t^*	a_t	y_t^*	π_t^*	a_t	y_t^*	π_t^*
$s_g = \tau^D = 0.2$	y_t	86.31	0.52	13.17	8.01	2.31	89.68	73.10	11.02	15.87
	c_t	69.56	10.06	20.39	36.14	10.93	52.93	43.73	16.38	39.88
	n_t	90.19	0.51	9.30	4.84	2.51	92.65	97.38	1.05	1.57
$s_g = \tau^D = 0.4$	y_t	85.28	0.63	14.09	7.87	2.19	89.94	72.53	10.05	17.42
	c_t	77.63	7.37	14.99	30.59	6.69	62.72	46.86	15.51	37.63
	n_t	93.54	0.37	6.08	8.30	2.32	89.37	97.73	0.80	1.46
$s_g = \tau^D = 0.6$	y_t	83.38	0.82	15.80	7.52	2.10	90.39	71.89	8.73	19.38
	c_t	85.46	4.82	9.71	25.99	3.72	70.30	52.89	14.23	32.88
	n_t	96.50	0.23	3.27	17.20	2.05	80.76	98.23	0.53	1.24

Note: The numbers indicate the asymptotic variance decomposition at an infinite horizon, expressed in percent. y_t is output, c_t is consumption, and n_t is hours worked. The asymmetric shocks are domestic technology, a_t , foreign output, y_t^* and foreign inflation, π_t^* . The underlying calibration is as shown in Table 2.

Figure 2 gives a first insight as to why the welfare costs reported in Table 3 increase with public sector size. In order to understand the sources of the observed volatility, Table 5 reports the *unconditional* variance decomposition for the benchmark economy under the alternative monetary policies. Three exogenous shocks in the form of calibrated AR(1)-processes are considered: A domestic technology shock, a_t , a foreign output shock, y_t^* , and a foreign inflation shock, π_t^* . Under a money supply rule, the dominant source of fluctuations is the domestic supply shock, accounting for more than 95% of output volatility. Similarly, the technology shock accounts for more than 85% of output volatility under the Taylor rule. In contrast, when the exchange rate is pegged, then the foreign price shock plays the most important role, accounting for more than 90% of GDP volatility.

The intuition for these results can be provided by studying the uncovered interest parity condition. The combination of the Euler equations from domestic and foreign bond holdings yields:

$$R_t(1 + \phi_B'(B_{F,t})) = R_t^* \mathbb{E}_t [\Delta S_{t+1}], \quad (4.4)$$

relating the domestic nominal interest rate to the foreign nominal interest rate. In the long run, the domestic interest rate equals the foreign interest rate, while in the short run, the expected change in the nominal exchange rate captures deviations in the interest rates. The portfolio adjustment costs alter the uncovered interest parity condition from the one given by complete financial markets.³⁸ Under flexible exchange rates, the expected change in the nominal exchange rate dampens the impact of foreign shocks to the domestic economy and the home country is mainly affected by domestic disturbances. By contrast, when the central bank fixes the rate of exchange, the domestic interest rate equals the foreign interest rate, so that foreign inflation shocks get transmitted to the domestic interest rate.

³⁸The standard uncovered interest parity relationship can be derived by log-linearization (See Gali and Monacelli (2005) for details).

The effect of government size on the variance decomposition of output is minor, however, government size has sizable effects on the variance decomposition of consumption on hours. Under flexible exchange rates, the impact of foreign shocks on consumption is reduced when government size increases. On the other hand, the role of the domestic supply shock diminishes with increasing government size under pegged exchange rates. Concerning hours of work, we observe that the domestic technology shock gains importance with increasing government size under all monetary policy specifications.

4.3 Dynamics

To shed light on the preceding results, it is useful to inspect the model dynamics. In a first step, the discussion will focus on how these depend upon the size of the public sector. To establish a benchmark, it is assumed that monetary policy follows an exogenous money supply rule with completely flexible exchange rates. As follows from Table 5, the domestic technology shock is the main driving force under such a policy. To this end, impulse response functions (IRFS) for a selection of variables corresponding to a one percent increase in domestic technology are reported. To investigate the role of government size, the dynamics under different calibrations of the public sector are compared. In a second step, the implications of changing the exchange rate policy to a strict peg are discussed and a link between government size and the exchange rate regime is established.

4.3.1 Floating exchange rates

Figure 3 shows the dynamic responses of selected variables for the benchmark calibration and for a small and large government respectively.³⁹ The benchmark is indicated by solid black lines. A positive shock to domestic technology raises output and lowers prices. Since there is monopolistic competition among intermediate goods producing firms and price adjustments are costly, firms save on labor demand, causing hours worked to fall. The increase in output brings about an increase in consumption demand.

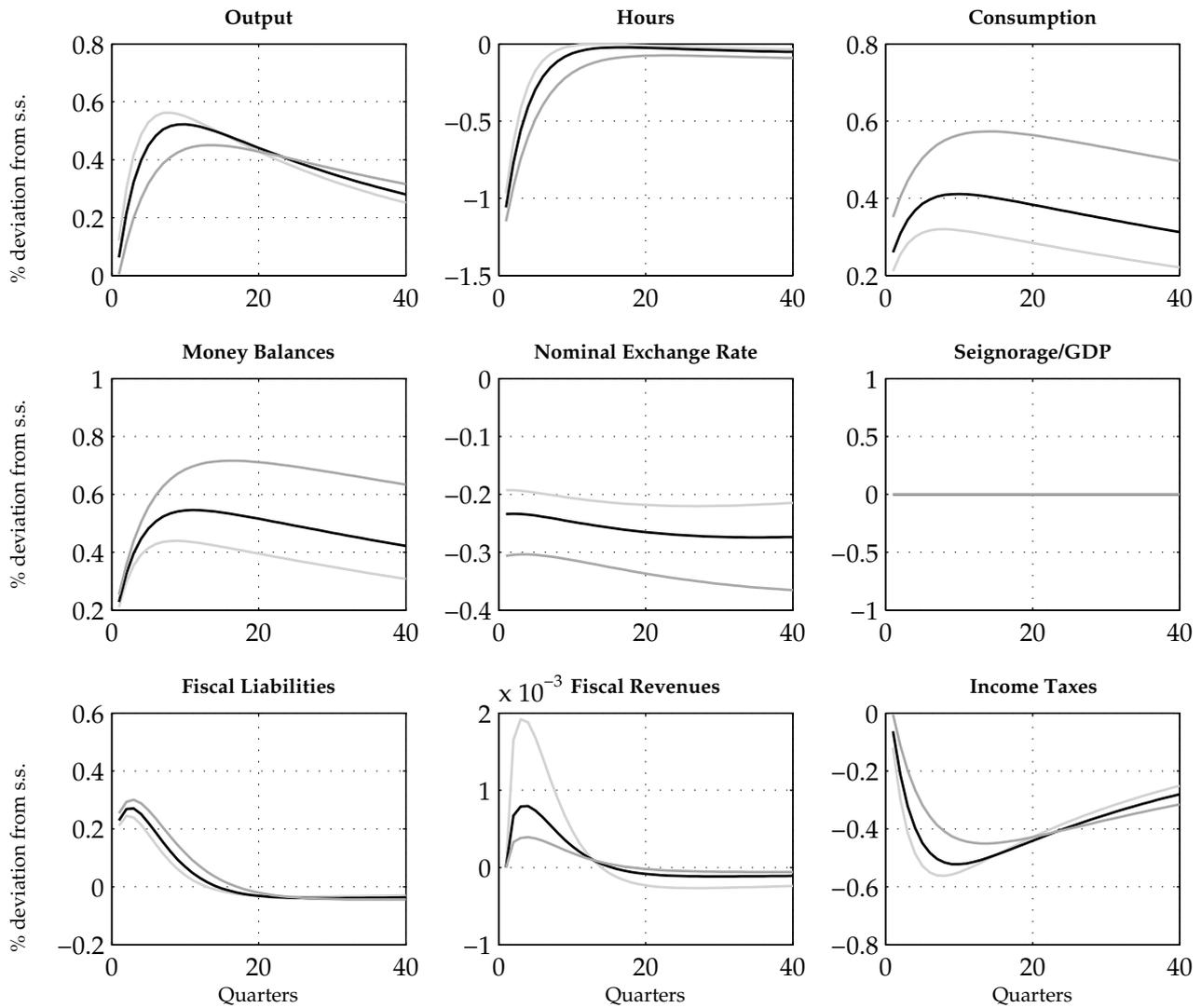
The central bank implements a constant money supply rule and allows for floating exchange rates. The fall in domestic inflation implies an increase in the demand for real money balances, causing the nominal exchange rate to appreciate. With such a rule, the nominal money transfers from the central bank to the government (seignorage) are constant. Government liabilities increase by a sizable amount and remain persistently above the steady state for 20 quarters. At the same time, the government budget displays a surplus. Although income taxes decrease persistently, government revenues increase, while government spending remains constant.

The role of government size can be highlighted by comparing the impulse responses for different calibrations of the public sector (s_g and τ^d). This result is also depicted in Figure 3. A large government implies lower dynamics of output. Hours worked, consumption and real money balances are more responsive when the public sector is large. The nominal exchange rate appreciates

³⁹The dynamics to a foreign output shock (Figure 6) and a foreign inflation shock (Figure 7) are reported in the appendix.

more strongly and government liabilities increase more compared to the benchmark case. The lower response of output under a large government implies lower tax revenues such that fiscal revenues increase more the smaller the public sector.

Figure 3: Impulse responses to a 1% domestic productivity shock, varying government size



Note: — Small $s_g = \tau^D = 0.2$ — Benchmark $s_g = \tau^D = 0.4$ — Large $s_g = \tau^D = 0.6$

Composition effect. To better understand the effects of government size on volatility and dynamics, it is instructive to disentangle the public sector into its expenditure side, s_g , and revenue side, τ^D . First, the increase in public spending affects the economy through a *composition effect* which is closely linked to the automatic stabilization properties of government size.⁴⁰ In short, the composition effect captures the following: Larger governments reduce the volatility of output because government spending is not volatile itself. Increasing the size of that (non-volatile) component of GDP decreases ceteris paribus the overall volatility (see also Figure 2). Consider the aggregate resource constraint

⁴⁰For a detailed discussion see e.g. Andrés and Doménech (2006) and Andrés, Doménech, and Fatas (2008).

given by equation (2.31) in log-linearized form

$$\hat{y}_t = s_c \hat{c}_t + s_i \hat{i}_t + s_g \hat{g}_t + (s_g - 1) \hat{p}_{H,t}. \quad (4.5)$$

Note that the present experiment assumes constant government spending, such that $\hat{g}_t = 0$. Changing the share of public purchases, s_g , means changing the composition of the aggregate demand components (s_c, s_i) , which both depend negatively upon the size of government spending. The expression $(s_g - 1) \hat{p}_{H,t}$ arises because government spending has full home bias. It captures the fact that the government is immune to exchange rate risk as its expenditures are paid in domestic currency only. The response of domestic prices amplifies the composition effect, as the elasticity on deviations in the domestic price level $(s_g - 1)$ decreases with government size.⁴¹ Following a domestic supply shock, the fall in domestic prices has a stronger positive effect on aggregate demand when government size is small. While output volatility is reduced by the composition effect, the volatility of private consumption is substantially enhanced. As the non-volatile public sector increases, the private sector is forced to absorb a larger fraction of the volatility in the economy. Taken together, the composition effect provides an explanation for the dampened response of output and the stronger reaction of consumption when government expenditures are large. However, the composition effect is not sufficient to understand why welfare decreases with public sector size.

Labor supply effect. The role of income tax rates, τ^D , is studied next. The size of the tax distortion has a direct impact on consumption and the labor supply decision. On the one hand, variations in income taxes give rise to a typical *wealth effect*. As can be observed in Figure 3, lowering τ^D directly expands after tax income, untightening thereby the household's budget constraint and thus amplifying the consumption schedule. On the other hand, the tax-elasticity $\frac{\tau^D}{1-\tau^D}$ increases with the level of taxes.

$$v \hat{n}_t = -\sigma \hat{c}_t + \hat{w}_t - \frac{\tau^D}{1-\tau^D} \hat{t}_t^D. \quad (4.6)$$

Hence, as equation (4.6) shows, an increase in the size of public revenues leads to a higher impact of changes in the tax rate and thus on the labor supply decision of households, i.e., destabilizing hours worked. Note that changes in government size (on the revenue or expenditure side) do not affect the labor supply elasticity, v . As shown by Guo and Harrison (2006), the results reported in Gali (1994) essentially depend on the assumption of the household's period utility function and the associated *employment effect*. Under the log-log preference specification of Gali (1994), the calibration of public sector size determines the elasticity of labor supply through steady state adjustments of employment, which results in the main driver of his results. To shut down the employment effect of government size, Guo and Harrison (2006) suggest to use a convex preference specification, similar to the one used in this paper. It has the advantage of featuring an inverse Frish labor supply elasticity, $\frac{1}{v}$, which is independent of \bar{n} . The preference specification used herein is a further generalization of the one used

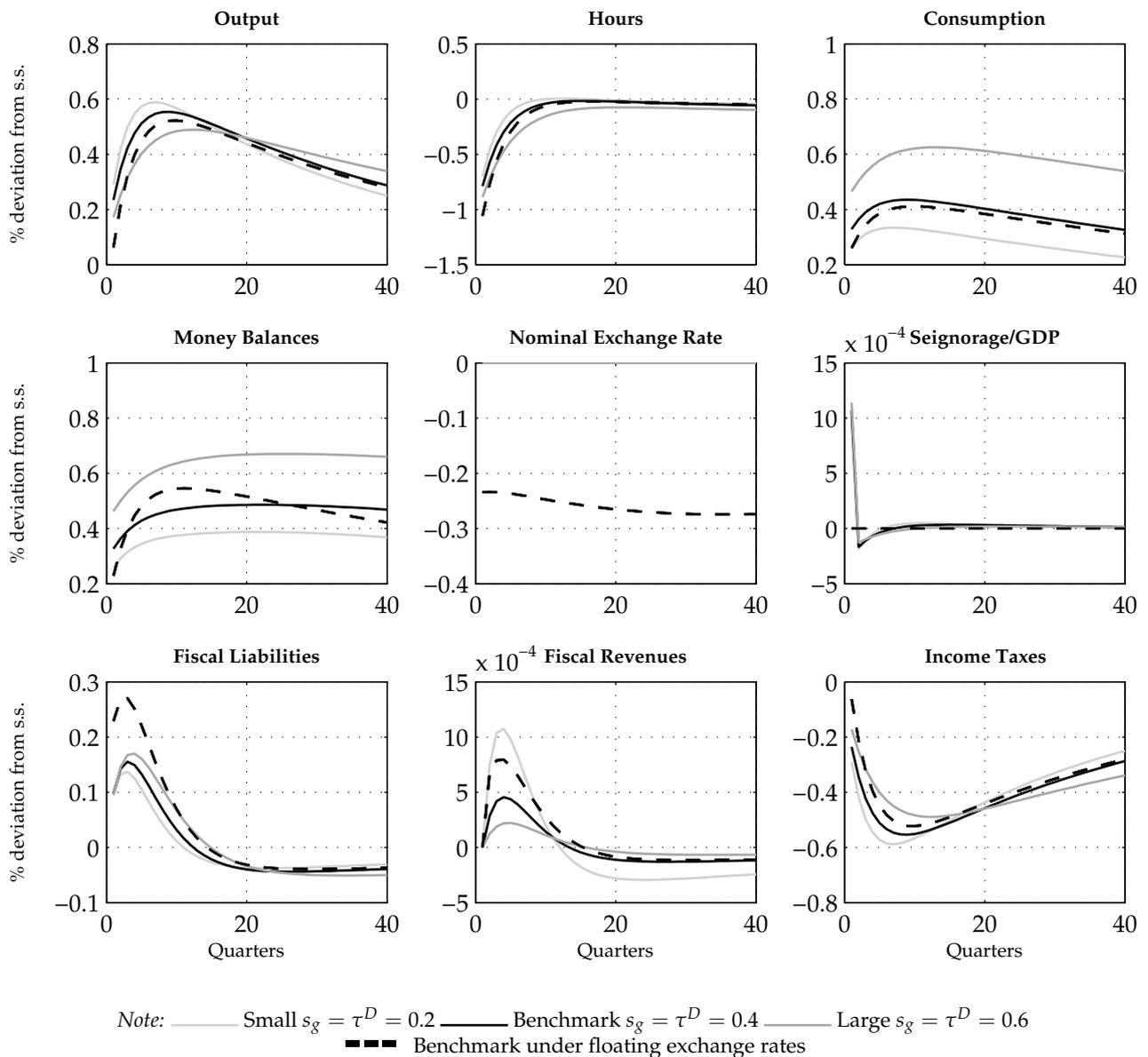
⁴¹The model has been tested under the assumption that the government consumes the aggregate final good rather than only the domestically produced good, that is it pays $P_t g_t$. Under this assumption, the qualitative nature of the results does not change. In comparison to the benchmark, net welfare gains of flexible exchange rates are larger. They remain increasing in government size.

in Guo and Harrison (2006) and further allows to test the model implications for different degrees of consumption smoothing. As we shall see in Section 5, the assumptions on the degree of labor supply elasticity and intertemporal elasticity of substitution have quantitative effects on the main results, but qualitatively, the results are robust to any specification.

4.3.2 Pegging the exchange rate

The labor supply equation (4.6), and in particular the size and dynamics of the income tax rate, fundamentally relates to the question of how the exchange rate regime affects model dynamics, volatility and thus the welfare results presented in Table 3.

Figure 4: Impulse responses to a 1% domestic productivity shock, comparing exchange rate policies



The starting point for understanding the government's tax policy is to consider the government

budget constraint provided in Equation 2.18 and the fiscal rule in Equation 2.24.⁴² The government generates revenues from taxing the household's labor and capital income, from interest payments on issued bonds and from seignorage.⁴³ The fiscal rule in place stipulates that any positive (negative) deviation of government liabilities (interest bearing domestic bonds plus non-interest bearing money holdings) in the previous period from its long run value leads to an increase (decrease) in tax revenues that the government should collect ($\gamma_1 > 0$). If the central bank runs an exogenous money supply rule and allows for a flexible exchange rate, then seignorage revenues are constant and do not affect the government's budget (as depicted in Figure 3). In turn, when the monetary authority credibly pegs the exchange rate, the money stock in the economy has to be adjusted, rendering money supply endogenous and generating seignorage revenues to the government. Consequently, the government can hold less debt, explaining why liabilities increase less strongly. Moreover, the additional revenue gives the government the ability to reduce income taxes and still generate a primary surplus. Figure 4 depicts this mechanism and allows to compare the benchmark dynamics of Figure 3 under floating exchange rates with its counterpart under an exchange rate peg and for different calibrations of government size.

Under an exchange rate peg, the response of output to a technology shock is stronger than under the float. In order to maintain the exchange rate peg credible and counter the pressure of appreciation, the monetary authority increases money supply (as shown by the response of real money balances), reducing thereby also the downward pressure on CPI inflation. Figure 4 shows that the government generates revenues from money creation on impact, although the effect is small and not persistent. We observe that the response of government liabilities is smaller, given the fact that the government holds less debt to finance its expenditures than under a floating regime. Further, the government can reduce income taxes by a larger amount, which in turn leads to a more pronounced response of consumption and a smaller reduction in hours worked. The implications of changing the size of the government purchases are the same as under floating exchange rates.

To sum up, public sector size affects the results reported in Table 3 through two main channels. On the one hand, we observe a *composition effect*, reducing the volatility of output by automatic stabilization, but increasing substantially the volatility of consumption. This effect is enhanced under pegged exchange rates, where the monetary authority loses a policy instrument and is forced to adjust money supply endogenously to unexpected shocks. The additional seignorage revenues distort the tax decision of the government and generate more volatility in the private sector. On the other hand, we observe a *labor supply effect*. Essentially, changes in monetary policy play a central role in the tax decision of the government, which affects the labor supply decision of the households and generates additional volatility in hours worked. The large differences in welfare costs across exchange rate regimes are an outcome of these mechanisms in which government size plays a crucial role.

⁴²The government sets deviations of lump-sum taxes to zero, ($\hat{\tau}^L = 0$).

⁴³Importantly, as it is common to low-inflation developed countries, seignorage adds little to total government revenues. Similar to what is observed in the data, the steady state share of seignorage in GDP ($\frac{\bar{m}}{y}$) equals 0.62%.

5 Discussion of the results

This section discusses the sensitivity of the results presented above by varying assumptions about three main dimensions of the benchmark model. The first concerns fiscal policy, in particular the effect of distortionary taxation and the fiscal rule in place. Second, it has been shown that monetary policy operated by an optimal simple interest rate rule yields the best welfare properties. This section discusses in detail how these results depend upon the specification of such a policy rule. Finally, the benchmark parametrization depends upon values taken from the related literature. This section will provide insights on how the results depend on changes in the parameter values, with a particular focus on labor supply elasticity and the degree of trade openness. Overall, the results are qualitatively robust to the different changes in policies and parametrization. However, depending on the fiscal and monetary policy in place, or the parametrization assumed, there can be substantial quantitative differences in the welfare costs of adopting a peg as a function of public sector size.

5.1 The role of fiscal policy

The analysis of the benchmark model with distortionary income taxation has delivered two central results. The welfare costs of adopting an exchange rate peg increase with public sector size and the main drivers of these costs are the composition and labor supply effects. Therefore, an important role in determining the welfare costs corresponds to the assumptions on fiscal policy, i.e., the tax policy and fiscal rule that are implemented.

Table 6: Welfare costs of exchange rate peg, comparing fiscal policies

Exchange rate policy ⁽ⁱ⁾	Benchmark			Lump-sum taxation			Expenditure rule		
	20%	40%	60%	20%	40%	60%	20%	40%	60%
Government size ⁽ⁱⁱ⁾									
Fully flexible ⁽ⁱⁱⁱ⁾	-2.42	-3.46	-6.97	-2.46	-3.72	-6.62	-2.72	-4.51	-9.20
Managed float ^(iv)	-2.48	-3.65	-7.78	-2.52	-3.88	-7.15	-2.76	-4.55	-9.15

Note: (i) The welfare gain Θ is the % fraction of consumption required to equate welfare under any given policy to the one obtained under a peg. (ii) $s_g = \tau^D$. (iii) The fully flexible exchange rate regime is characterized by a money supply rule as specified in equation 2.19. (iv) The managed float is characterized by an optimal simple Taylor rule given by equation 2.21.

5.1.1 Distortionary vs. lump-sum taxation

When the government chooses its tax policy to be lump-sum ($\hat{\tau}_t^d = \bar{\tau}^D$) rather than distortionary ($\hat{\tau}_t^L = \bar{\tau}^L$), the labor supply equation in log-linearized terms reads

$$v\hat{n}_t = -\sigma\hat{c}_t + \hat{w}_t. \quad (5.1)$$

In that case, the labor supply effect of distortionary taxation vanishes. In particular, the income tax rate affects the welfare results solely through its negative level effect on the steady state of labor. If government spending is financed through time-varying lump-sum taxes, then the exchange rate

policy affects the dynamics of lump-sum taxes rather than the distortionary tax rate, which in turn affects directly the household's budget constraint but not the labor supply decision. Consequently, hours worked are less volatile and the welfare costs of adopting an exchange rate peg are significantly lower.

The second column of Table 6 compares the welfare costs arising from a lump-sum tax policy to the benchmark results presented in Section 4. Two points are important to highlight here. First, net welfare gains of flexible exchange rates remain increasing in government size under both the fully flexible and managed floating exchange rate arrangement. Second, compared to the benchmark, the welfare costs of implementing a peg are slightly higher when the government is small, but substantially lower as the public sector gets large. A closer inspection of the variance contribution, reported in Table 7, reveals that the composition effect outweighs the labor supply effect. Even though taxes no longer distort the labor supply decision, it can be seen that the variance of consumption largely increases with public sector size.

5.1.2 Revenue vs. expenditure rule

So far it has been assumed that fiscal policy is designed by a rule which stipulates that tax revenues adjust to the level of government liabilities observed in the past period. However, it can be argued that cyclical changes in tax rates are not very realistic.⁴⁴ Moreover, empirical evidence on fiscal consolidations in industrialized countries indicates that fiscal rules have been more successful when based on adjustments in government spending rather than adjustments in the tax rate.⁴⁵ Therefore, as a robustness exercise, a fiscal rule similar to the one of Andrés and Doménech (2006) is adopted. With such a rule, the deviation of public spending from its long-run value is a function of the deviation of the past liabilities from its target:

$$\frac{g_t}{\bar{g}} = \left(\frac{l_{t-1}}{\bar{l}} \right)^{-\gamma_1}. \quad (5.2)$$

With an expenditure rule the government lowers its spending when last period's government liabilities have been above their steady state value, i.e., $-\gamma_1$. This is in contrast to the parametrization of the benchmark experiment, where tax revenues were raised instead. With setting $\gamma_1 = 0.25$ it is ensured that fiscal policy under this rule is passive.⁴⁶ Under such a policy, the tax instruments τ^L, τ^D are both set constant at their long-run values, and government spending is the only fiscal variable allowed to adjust.

The welfare results of changing the fiscal rule are summarized in the last column of Table 6. First, it is shown that also under this fiscal specification the net welfare gains of flexible exchange rates increase with government size. However, compared to the benchmark, the welfare costs of adopting a peg are substantially higher under a revenue rule. Considering the welfare costs of eliminating the

⁴⁴Furthermore, distortionary taxes may, under some circumstances, lead to multiple (sunspot) equilibria, inducing additional instability (Schmitt-Grohé and Uribe, 1997).

⁴⁵See for instance Alesina and Perotti (1995) or Alesina and Ardagna (2010).

⁴⁶To provide equivalence and comparability of the expenditure and revenue rule, the value of γ_1 is set such that the half-life response of output to the domestic technology shock, i.e., after 20 periods, is equal under the two rules.

business cycle and the variance contributions presented in Table 7, it can be seen that this is the result of substantially lower aggregate volatility.

With constant taxation (lump-sum and distortionary), deviations in fiscal revenues are proportional to deviations in output. A domestic supply shock causes *ceteris paribus* an increase of output, i.e., income, thus raising fiscal revenues. The government can reduce its debt holdings causing total government liabilities to decrease. Given the fiscal rule of equation 5.2, government spending increases. This procyclical pattern of government spending induces a demand effect, diminishing the downward pressure on prices following the technology shock. Further, the increase in government spending affects the household's consumption and labor decision through a typical wealth effect. The exchange rate policy affects this mechanism mainly through the demand side effect of fiscal policy. Under a floating regime, domestic prices fall in response to a technology shock and the nominal exchange rate is allowed to depreciate. These dynamics are mitigated by procyclical fiscal expenditures. When the exchange rate is pegged instead, monetary policy is exogenous, implying an amplification of the demand side effects of procyclical fiscal policy, increasing the volatility in prices. This increase in volatility feeds into hours and consumption, therefore destabilizing the whole economy.

Table 7: Welfare compensation and variance contribution for different fiscal policies

Statistic ⁽ⁱ⁾	Fully flexible			Strict peg			Managed float		
	0.2	0.4	0.6	0.2	0.4	0.6	0.2	0.4	0.6
Government size⁽ⁱⁱ⁾									
Benchmark									
Welfare ϑ^{Policy}	-1.72	-2.98	-7.04	-8.93	-11.25	-22.09	-1.90	-1.91	-2.00
Fixed distortionary taxes									
Welfare ϑ^{Policy}	-1.60	-2.27	-3.37	-7.94	-8.02	-9.16	-1.89	-1.91	-2.01
Consumption $\vartheta_{V,c}$	-1.09	-1.50	-2.16	-2.41	-3.69	-6.04	-0.34	-0.39	-0.49
Hours worked $\vartheta_{V,n}$	-0.32	-0.51	-0.85	-5.48	-4.37	-3.29	-1.32	-1.30	-1.31
Expenditure rule									
Welfare ϑ^{Policy}	-1.22	-1.28	-1.43	-8.24	-8.23	-8.21	-1.89	-1.87	-1.86
Consumption $\vartheta_{V,c}$	-0.84	-0.85	-0.89	-1.68	-1.72	-1.85	-0.33	-0.35	-0.37
Hours worked $\vartheta_{V,n}$	-0.25	-0.31	-0.42	-6.44	-6.38	-6.22	-1.32	-1.29	-1.26

Note: (i) Welfare costs are stated in per-mil of steady state consumption. (ii) $s_g = \tau^D$.

5.2 The role of the monetary policy

Besides the specification of fiscal policy, it is important to scrutinize the welfare performance of alternative optimal simple monetary policy rules. So far, it was assumed that the monetary policy conducts an interest rate rule with smoothing, stabilizing inflation, output and changes in the exchange rate. In continuation, this rule is compared to the following Taylor rules: (i) *Inflation only*; (ii) *Inflation and output*; (iii) *Inflation and changes in the nominal exchange rate*; (iv) *Domestic inflation only*; (v) *Domestic inflation and output*; (vi) *Domestic inflation, output and changes in the nominal exchange rate*. Table 8 reports the results. All rules are evaluated with and without interest rate smoothing. The reaction parameters for the given policy rules are estimated such that the highest level of unconditional

welfare in the home economy is attained.

Table 8: Welfare compensation of implementing an exchange rate peg for different monetary policies

Rule ⁽ⁱ⁾				No smoothing ⁽ⁱⁱⁱ⁾			Smoothing ^(iv)		
Government size ⁽ⁱⁱ⁾				0.2	0.4	0.6	0.2	0.4	0.6
Benchmark				-2.25	-3.25	-6.96	-2.25	-3.25	-6.96
(i)	$\gamma_\pi > 0$	$\gamma_y = 0$	$\gamma_e = 0$	-2.41	-3.67	-8.43	-2.41	-3.67	-8.43
(ii)	$\gamma_\pi > 0$	$\gamma_y > 0$	$\gamma_e = 0$	-2.25	-3.25	-6.98	-2.25	-3.25	-6.98
(iii)	$\gamma_\pi > 0$	$\gamma_y = 0$	$1 \geq \gamma_e > 0$	-2.33	-3.46	-7.72	-2.33	-3.46	-7.72
(iv)	$\gamma_{\pi_H} > 0$	$\gamma_y = 0$	$\gamma_e = 0$	-2.39	-3.60	-8.15	-2.41	-3.67	-8.48
(v)	$\gamma_{\pi_H} > 0$	$\gamma_y > 0$	$\gamma_e = 0$	-2.25	-3.25	-6.97	-2.25	-3.25	-6.97
(vi)	$\gamma_{\pi_H} > 0$	$\gamma_y = 0$	$1 \geq \gamma_e > 0$	-2.24	-3.23	-6.92	-2.24	-3.23	-6.92

Note: (i) Θ is the % fraction of consumption required to equate welfare under any given policy to the one obtained under a peg. (ii) $s_g = \tau^D$. (iii) $\rho_R = 0$. (iv) $1 \geq \rho_R > 0$.

A number of implications are worth emphasizing. First, no matter which kind of optimal simple rule is implemented, pegging the exchange rate leads to welfare losses which are increasing in the size of government. However, the size of the loss varies according to the specification of the Taylor rule. Second, strict stabilization of CPI inflation always attains the highest level of welfare. This finding is consistent with a broad literature examining welfare-optimizing monetary policy in an open economy setting.⁴⁷ Such a rule implies that there is no trade-off between output gap stabilization and domestic price stability, and with no need for monetary policy to explicitly consider fluctuations in the exchange rate. Third, interest rate rules that feature nominal exchange rate stabilization have better welfare properties than those rules which do not include the exchange rate target. Fourth, in most cases, allowing for interest rate smoothing increases the welfare costs of adopting a peg. In other words, under flexible exchange rates the interest rate rules with interest rate smoothing yield higher welfare results. Finally, whether targeting domestic inflation or CPI inflation does not have a substantial impact on welfare.

Table 9 summarizes the estimated reaction parameters of the interest rate rules. The interest rate rule which targets CPI inflation only yields a coefficient γ_π at the upper bound of 5, completely stabilizing inflation. This does not change when interest rate smoothing is included in the rule. Adding the stabilization of output to the Taylor rule reduces the inflation coefficient to standard values found and typically used in the business cycle literature. The coefficient on output is around 1, which is a rather high value. When interest rate smoothing is included, the coefficient on inflation is reduced and the one on output increased. Notably, the output coefficient decreases with government size, which is related to the automatic stabilizer effect of government size discussed in Section 4.2. Finally, adding the nominal exchange rate target to the rule instead of output stabilization reveals that a pure float is not optimal, rather the interest rate should be adjusted to take into account the fluctuations in the nominal exchange rate.

⁴⁷See for example Gali and Monacelli (2005), Bergin, Shin, and Tchakarov (2007) or Faia and Monacelli (2007).

Table 9: Estimated parameters of different optimal simple monetary policy rules

Rule ⁽ⁱ⁾				No smoothing ⁽ⁱⁱⁱ⁾			Smoothing ^(iv)			
				0.2	0.4	0.6	0.2	0.4	0.6	
Government size ⁽ⁱⁱ⁾										
Benchmark				γ_π	1.15	1.30	1.30	1.14	1.15	1.30
				γ_y	0.25	0.98	1.00	0.23	0.29	1.00
				γ_e	0.02	0.27	0.28	0.02	0.04	0.28
				ρ_R	—	—	—	0.12	0.16	0.04
(i)	$\gamma_\pi > 0$	$\gamma_y = 0$	$\gamma_e = 0$	γ_π	∞	∞	∞	∞	∞	∞
				ρ_R	—	—	—	0.00	0.03	0.01
(ii)	$\gamma_\pi > 0$	$\gamma_y > 0$	$\gamma_e = 0$	γ_π	1.25	1.25	1.23	1.17	1.17	1.18
				γ_y	0.98	0.96	0.92	1.55	1.45	1.29
				ρ_R	—	—	—	0.54	0.58	0.64
(iii)	$\gamma_\pi > 0$	$\gamma_y = 0$	$1 \geq \gamma_e > 0$	γ_π	1.44	1.47	1.76	∞	∞	∞
				γ_e	0.32	0.36	0.60	0.81	0.82	0.82
				ρ_R	—	—	—	0.54	0.58	0.64

Note: (i) The parameter space of γ_π is bounded between $[1, 5]$ as in Bergin, Shin, and Tchakarov (2007). When the upper level of the parameter space is reached, then the value of the coefficient is indicated by ∞ . γ_y is between $[0, 5]$, γ_e and ρ_R are between $[0, 1]$. (ii) $s_g = \tau^D$. (iii) $\rho_R = 0$. (iv) $1 \geq \rho_R > 0$.

5.3 Parameter sensitivity

Finally, it is examined how the predictions of the benchmark model are affected by changes in the parametrization. For this exercise, a welfare metric similar to the one of Equation 3.7 is computed. However, instead of using a specific Taylor rule as flexible exchange rate case, here the money supply rule is used as reference. The expression then reads

$$\Omega = \left\{ \left(\mathcal{W}_{0,t}^{Peg} - \mathcal{W}_{0,t}^{MSrule} \right) (1 - \beta)(1 - \sigma) + 1 \right\}^{\frac{1}{1-\sigma}} - 1, \quad (5.3)$$

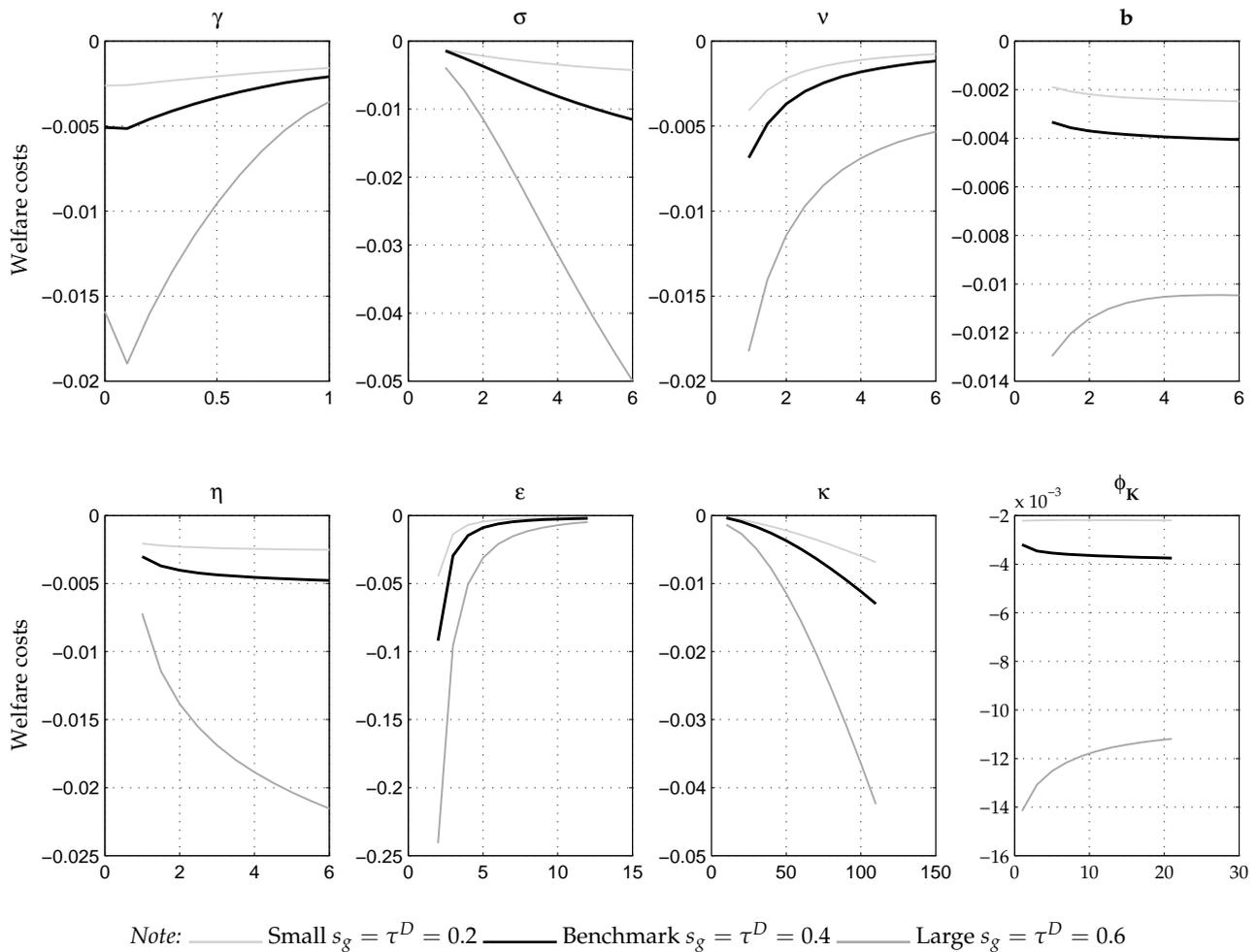
in which Ω is the fraction of household's consumption that would be needed to equate conditional welfare under the money supply rule to the one under a strict peg. Figure 5 displays these welfare costs. In the first row, parameters concerning the preferences of the household are varied. The parameter range is chosen such that values are in line with empirical findings, the business cycle literature and that equilibrium stability is ensured. Openness, γ , varies between $[0, 1]$, the intertemporal elasticity of substitution in consumption, σ , and in money balances, b , as well as the labor supply elasticity, ν , vary between $[1, 6]$.⁴⁸ The second row reports variation in net welfare gains for different degrees of the elasticity of substitution between domestic and foreign goods, η , between $[1, 6]$; the elasticity of substitution between differentiated goods, ϵ ; the degree of price adjustment costs, $\kappa \in [10, 110]$; and the cost of adjusting the capital stock, $\phi_K \in [0, 20]$.

First and foremost, the qualitative nature of the results presented in Section 4 is preserved for all parametrizations studied. The costs of adopting an exchange rate peg increase with government size. The variation in parameters can, however, reduce the difference in welfare costs that arises

⁴⁸ ν is the inverse of the Frish labor supply elasticity, analytically: $e^\nu = \frac{U_n}{n \left[U_{mn} - \frac{U_{nk}^2}{U_{cc}} \right]} = \frac{1}{\nu}$.

under different sizes of the public sector. For instance, the difference in welfare costs decreases with the country's degree of trade openness or elasticity of substitution between intermediate goods. The contrary is the case for the elasticity of substitution in consumption and the degree of price stickiness. In continuation, two parameters which are at the core of the main results will be discussed in more detail.

Figure 5: Welfare costs of adopting a strict peg for different parametrizations



5.3.1 Labor supply elasticity

The empirical literature focusing on estimating the labor supply elasticity reports values in the range of 0 – 0.5 for microeconomic estimates, whereas in macroeconomic models the values mostly used for this elasticity range between 2 – 4.⁴⁹ Intuitively, all else equal, the lower the labor supply elasticity, the more willing households are to work if wages increase. For a calibration of ν at a low value, for instance $\nu = 1$, hours worked are more responsive to changes in the real wage and its volatility is higher. The stabilizing effect of government spending on hours worked under an exchange rate peg

⁴⁹See Chetty, Guren, Manoli, and Weber (2011) and Peterman (2012) for overviews.

gains importance when the labor supply elasticity is low. On the other hand, when the labor supply elasticity attains a high value, the stabilizing effect of government expenditures on hours worked under an exchange rate peg loses importance, hence welfare costs of changing the exchange rate regime are reduced. As displayed in the first row of Figure 5, the welfare costs of moving from a money supply rule to a pegged exchange rate regime are high when the elasticity is low, and welfare costs decrease the larger the elasticity. Importantly, the qualitative results from Section 4 with respect to the role of government size remain.

5.3.2 Elasticity of substitution between domestic and foreign goods

Finally, the extent to which the elasticity of substitution between domestic and foreign goods affects the welfare costs is considered, since empirical studies have reported a variety of values ranging from 0.2 to 3.5.⁵⁰ For comparison, the elasticity of substitution between goods produced in different countries is assumed to take on values between 1 and 6. Intuitively, the foreign shocks dominate the volatility of output, hours worked and consumption under an exchange rate peg (See also Table 5). A high elasticity of substitution between foreign and domestic goods translates into higher volatility of the different consumption aggregates and hence to higher volatility of overall consumption. The elasticity η amplifies the destabilizing effect of government size on consumption, implying that the volatility of consumption would be highest for $\eta \rightarrow \infty$, i.e., when the domestic and foreign goods are perfect substitutes. Two results stand out. On the one hand, we have the fact that the larger η , the higher the welfare costs of adopting a peg. On the other hand, for a large government size, the welfare costs increase more strongly than for small governments.

6 Conclusion

The starting point of this paper has been the recent vision of the Bretton Woods Committee together with the initiative of the International Monetary Stability Board to reform the international monetary system towards an exchange rate regime which features less market fluctuations in the nominal exchange rates. As part of this ongoing debate, Schwartz (2000) linked the viability of an exchange rate peg, which is a similar regime to the one envisioned by the reform plans, to the size of the government sector. According to her point of view, a system of fixed exchange rates is not desirable when governments are large.

The present paper provides a quantitative investigation of this argument by studying how the net welfare gains of monetary policies with floating exchange rates over a fixed exchange rate change as a function of an economy's public sector size. The main findings are in support of Schwartz' view, as net welfare costs of adopting a peg are found to be increasing in government size. This result holds across many different monetary and fiscal policy specifications as well as for different parametrizations. The intuition is that countries with a larger government sector induce more volatility in the private sector through a composition effect in aggregate demand and a labor supply effect arising

⁵⁰See Feenstra, Luck, Obstfeld, and Russ (2014) for an overview.

from distortionary income taxes. Through the lens of the admittedly simple framework, the results suggest that a return to an exchange rate arrangement in the style of Bretton Woods would come along with high welfare losses for countries with large public sectors.

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A Model outline

A.1 General equilibrium (Nominal)

Marginal utility of c	$U_{c,t}(\cdot) = \Lambda_t P_t$
Marginal utility of m/p	$U_{\frac{M}{P},t}(\cdot) = \Lambda_t - \beta \mathbb{E}_t [\Lambda_{t+1}]$
Marginal disutility of n	$-U_{n,t}(\cdot) = \Lambda_t (1 - \tau_t^D) W_t$
Domestic bond holdings	$\Lambda_t = \beta R_t \mathbb{E}_t [\Lambda_{t+1}]$
Foreign bond holdings	$\Lambda_t = \frac{\beta R_t^*}{(1 + \Psi_B'(S_t B_{F,t}))} \mathbb{E}_t \left[\frac{\Lambda_{t+1} S_{t+1}}{S_t} \right]$
Capital Accumulation	$k_{t+1} = (1 - \delta) k_t - \Psi_K(i_t, k_t) + i_t$
Investment decision	$\Lambda_t P_t = Q_t (1 - \Psi'_{K,i}(i_t, k_t))$
Tobin's Q	$Q_t = \beta \mathbb{E}_t \left[\Lambda_{t+1} P_{t+1} (1 - \tau_{t+1}^D) R_{t+1}^z + \right. \\ \left. Q_{t+1} ((1 - \delta) + \Psi'_{K,k}(i_t, k_t) - \Psi_K(i_t, k_t)) \right]$
CPI	$P_t = \left[(1 - \gamma) P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}$
Domestic good	$c_{H,t} = (1 - \gamma) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} c_t$
Imports	$c_{F,t} = \gamma \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} c_t$
Aggregate resources	$P_{H,t} y_t = P_t (c_t + i_t) + P_{H,t} g_t + NX_t + P_t \Psi_B(S_t B_{F,t}) + P_{H,t} y_t \Psi_P$
Domestic prices	$\frac{(\epsilon - 1)}{\epsilon} = mc_t - \frac{\kappa}{\epsilon} \left\{ \left(\frac{P_{H,t}}{P_{H,t-1}} - \bar{\pi}_H \right) \pi_{H,t} + \right. \\ \left. \beta \mathbb{E}_t \left[\left(\frac{P_{H,t+1}}{P_{H,t}} - \bar{\pi}_H \right) \pi_{H,t+1} \left(\frac{y_{t+1}}{y_t} \right) \left(\frac{\Lambda_{t+1}}{\Lambda_t} \right) \right] \right\}$
Domestic production	$y_t = a_t k_t^\alpha n_t^{(1-\alpha)}$
Labor demand	$\frac{W_t}{P_{H,t}} = (1 - \alpha) mc_t \frac{y_t}{n_t}$
Capital demand	$\frac{R_t^z}{P_{H,t}} = \alpha mc_t \frac{y_t}{k_t}$
Government budget	$M_t + B_{H,t} + P_{H,t} \tau_t = R_{t-1} B_{H,t-1} + M_{t-1} + P_{H,t} g_t$
Foreign Euler equation	$y_t^{*-\sigma} = \beta R_t^* \mathbb{E}_t \left[\frac{y_{t+1}^{*-\sigma}}{\pi_{t+1}^*} \right]$
Exports	$c_{H,t}^* = \gamma \left(\frac{P_{H,t}}{S_t P_t^*} \right)^{-\eta} y_t^*$
Net foreign assets	$S_t B_{F,t} = R_{t-1}^* S_t B_{F,t-1} + NX_t$
Net exports	$NX_t = P_{H,t} c_{H,t}^* - P_{F,t} c_{F,t}$

The equilibrium is closed by specifying the fiscal and monetary policies and the three exogenous shocks.

A.2 General equilibrium (Deflated)

Define the following for deflating the nominal equilibrium by the domestic CPI, P_t :

$$\lambda_t = \Lambda_t P_t; p_{H,t} = \frac{P_{H,t}}{P_t}; rer_t = \frac{S_t P_t^*}{P_t}; \Delta S_t = \frac{S_t}{S_{t-1}}; b_{F,t} = S_t B_{F,t}$$

$$\pi_t = \frac{P_t}{P_{t-1}}; \pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}; w_t = \frac{W_t}{P_t}; m_t = \frac{M_t}{P_t}; q_t = \frac{\Lambda_t}{Q_t}.$$

The functional forms are given as follows:

Utility function
$$U(\cdot) = \frac{c_t^{1-\sigma} - 1}{1-\sigma} + \frac{\vartheta}{1-b} \left(\frac{M_t}{P_t} \right)^{1-b} - \chi \frac{n_t^{1+v}}{1+v}$$

Capital adjustment costs
$$\Psi_K(i_t, k_t) = \frac{\psi_K}{2} \left(\frac{i_t}{k_t} - \delta \right)^2 k_t$$

Portfolio adjustment costs
$$\Psi_B(S_t B_{F,t}) = \frac{\psi_B}{2} S_t (B_{F,t} - \bar{B}_F)^2$$

Price adjustment costs
$$\Psi_P(\cdot) = \frac{\kappa}{2} \left(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - \bar{\pi}_H \right)^2 y_t$$

The fiscal and monetary policies as well as the exogenous shocks can take on the following forms

Tax policy:

Constant lump-sum tax
$$\tau_t^L = \bar{\tau}^L$$

Constant income tax
$$\tau_t^D = \bar{\tau}^D$$

Fiscal rule:

Revenue rule
$$\frac{\tau_t}{\bar{\tau}} = \left(\frac{l_{t-1}}{\bar{l}} \right)^{\gamma_1}$$

Monetary policy:

Flexible Regime (Money supply)
$$M_t = M_{t-1}$$

Managed Regime (Taylor rule)
$$\bar{R}_t = \bar{R} \left(\frac{P_t}{P_{t-1}} \right)^{\gamma_\pi} \left(\frac{y_t}{\bar{y}} \right)^{\gamma_y} \left(\frac{S_t}{S_{t-1}} \right)^{\frac{\gamma_e}{1-\gamma_e}}$$

Fixed Regime
$$S_{t+1} = S_t$$

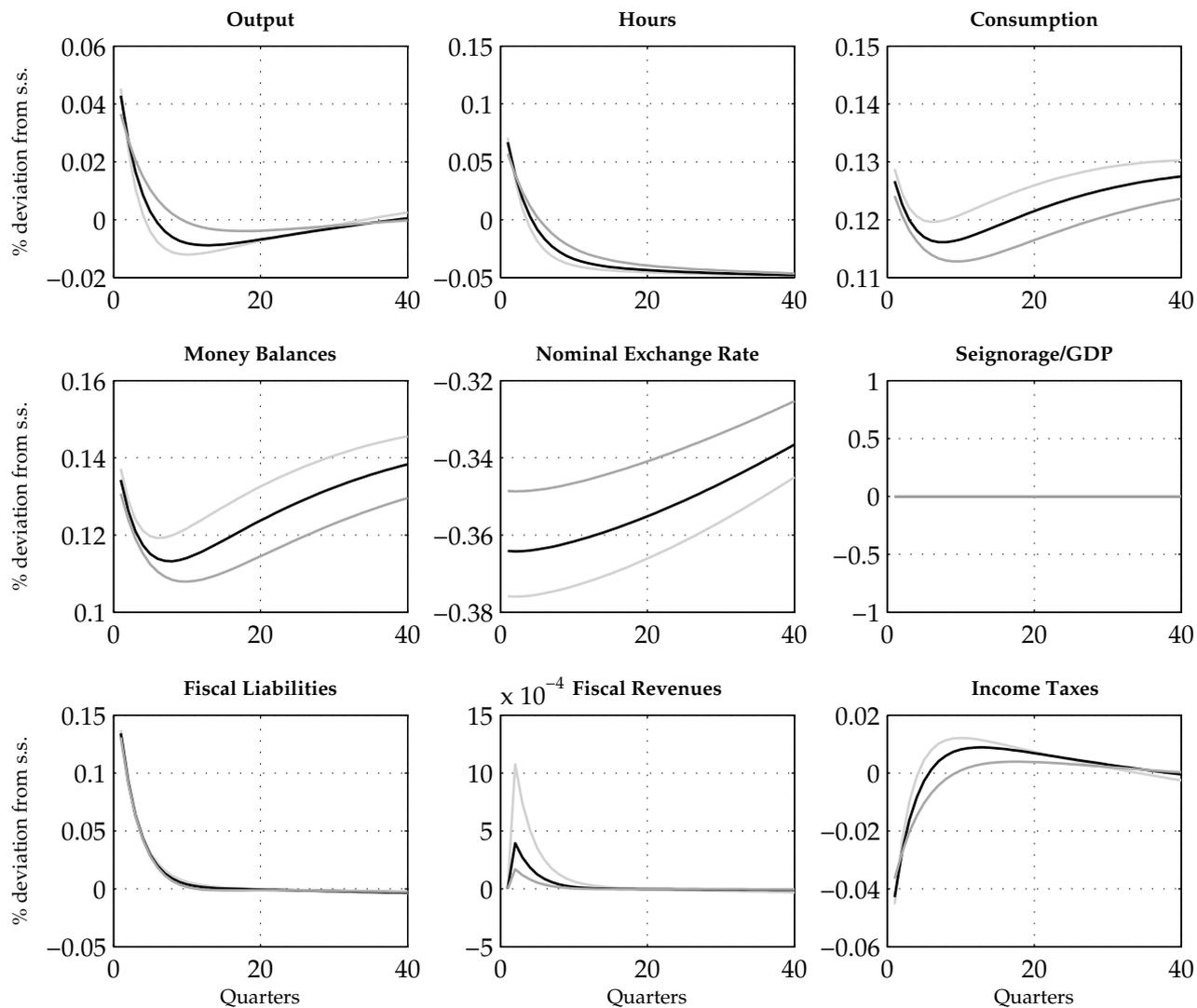
Shocks
$$\log(z_t) = \rho_z \log(z_{t-1}) + (1 - \rho_z) \bar{z} + \epsilon_{z,t} \quad \text{for } z = y^*, a, p^*$$

Then we can solve for the deflated general equilibrium given by the set of equations on the next page.

Marginal utility of c	$c_t^{-\sigma} = \lambda_t$
Marginal utility of m/p	$\vartheta m_t^{-b} = \lambda_t - \beta \mathbb{E}_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}} \right]$
Marginal disutility of n	$n_t^v = \lambda_t (1 - \tau_t^D) \omega_t$
Domestic bond holdings	$\lambda_t = \beta R_t \mathbb{E}_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}} \right]$
Foreign bond holdings	$\lambda_t = \beta \frac{R_t^*}{(1 + \psi_B b_{F,t})} \mathbb{E}_t \left[\frac{\lambda_{t+1} \Delta S_{t+1}}{\pi_{t+1}} \right]$
Capital Accumulation	$k_{t+1} = (1 - \delta)k_t - \frac{\psi_K}{2} \left(\frac{i_t}{k_t} - \delta \right)^2 k_t + i_t$
Investment decision	$q_t = \left(1 - \psi_K \left(\frac{i_t}{k_t} - \delta \right) \right)^{-1}$
Tobin's Q	$q_t = \beta \mathbb{E}_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left((1 - \tau_{t+1}^D) R_{t+1}^z + \right. \right. \\ \left. \left. q_{t+1} \left((1 - \delta) + \psi_K \left(\frac{i_{t+1}}{k_{t+1}} - \delta \right) \frac{i_{t+1}}{k_{t+1}} - \frac{\psi_K}{2} \left(\frac{i_{t+1}}{k_{t+1}} - \delta \right)^2 \right) \right) \right]$
CPI	$1 = (1 - \gamma) p_{H,t}^{1-\eta} + \gamma rer_t^{1-\eta}$
Domestic good	$c_{H,t} = (1 - \gamma) p_{H,t}^{-\eta} c_t$
Imports	$c_{F,t} = \gamma rer_t^{-\eta} c_t$
Aggregate resources	$p_{H,t} y_t = c_t + i_t + p_{H,t} g_t + n x_t + \frac{\psi_B}{2} (b_{F,t})^2 + p_{H,t} \frac{\kappa}{2} (\pi_{H,t} - \bar{\pi}_H)^2 y_t$
Domestic prices	$\frac{(\epsilon - 1)}{\epsilon} = mc_t - \frac{\kappa}{\epsilon} \{ (\pi_{H,t} - \bar{\pi}_H) \pi_{H,t} + \\ \beta \mathbb{E}_t \left[(\pi_{H,t+1} - \bar{\pi}_H) \pi_{H,t+1} \left(\frac{y_{t+1}}{y_t} \right) \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \right] \}$
Domestic production	$y_t = a_t k_t^\alpha n_t^{(1-\alpha)}$
Labor demand	$\frac{w_t}{p_{H,t}} = (1 - \alpha) mc_t \frac{y_t}{n_t}$
Capital demand	$\frac{R_t^z}{p_{H,t}} = \alpha mc_t \frac{y_t}{k_t}$
Government budget	$l_t = \frac{R_t}{\pi_t} l_{t-1} - m_t (R_t - 1) + R_t p_{H,t} (\bar{g} - \tau_t)$
Exports	$c_{H,t}^* = \gamma \left(\frac{p_{H,t}}{rer_t} \right)^{-\eta} y_t^*$
Money supply	$m_t = \frac{m_{t-1}}{\pi_t}$
Net foreign assets	$b_{F,t} = R_{t-1}^* \frac{\Delta S_t b_{F,t-1}}{\pi_t} + n x_t$
Foreign Euler equation	$y_t^{*- \sigma} = \beta R_t^* \mathbb{E}_t \left[\frac{y_{t+1}^{*- \sigma}}{\pi_{t+1}^*} \right]$
Net exports	$n x_t = p_{H,t} c_{H,t}^* - rer_t c_{F,t}$
Real exchange rate	$rer_t = \frac{\Delta S_t \pi_t^*}{\pi_t} rer_{t-1}$
Domestic price inflation	$p_{H,t} = \frac{\pi_{H,t}}{\pi_t} p_{H,t-1}$

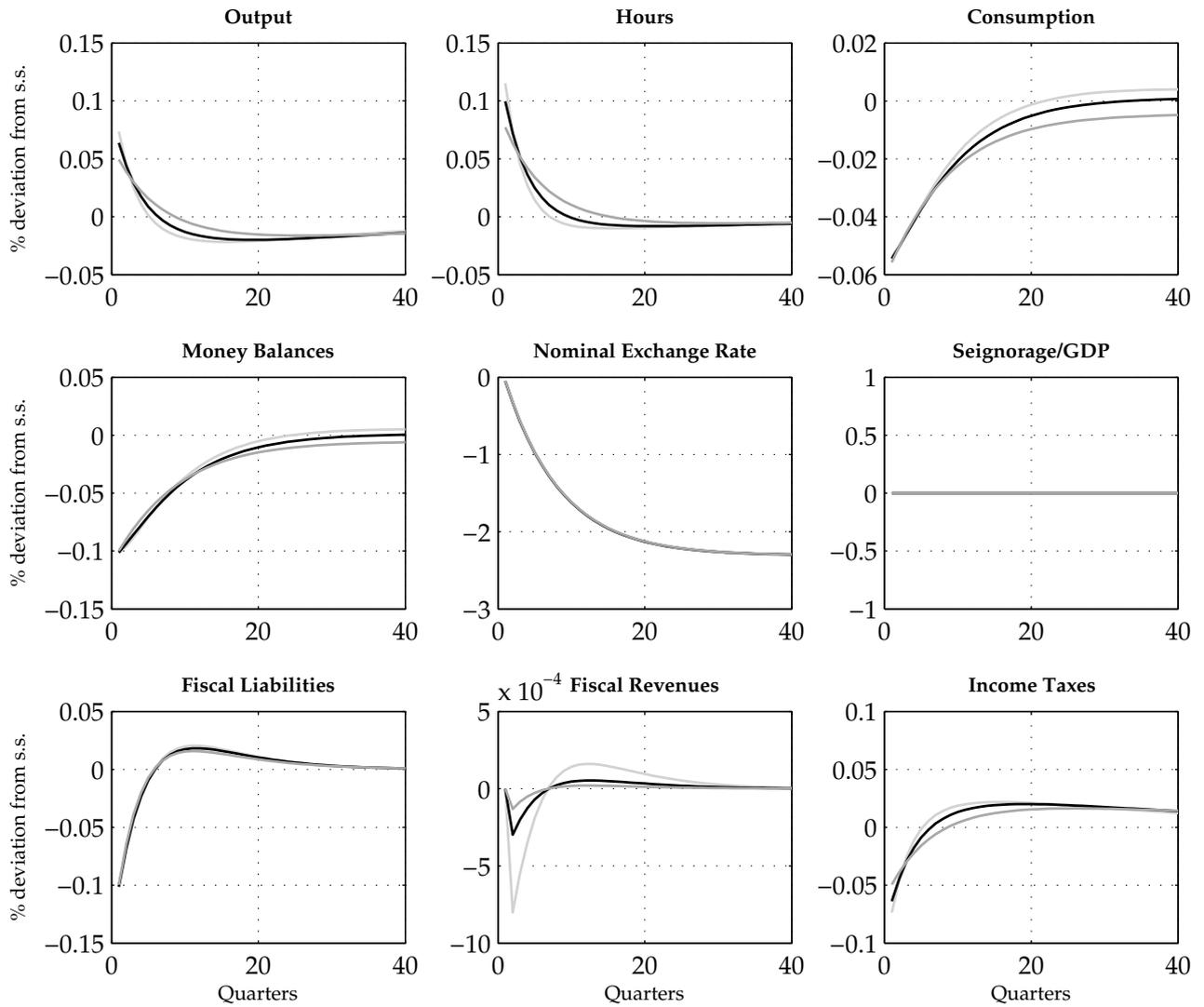
B Additional figures

Figure 6: Impulse responses to *foreign output shock*; money supply rule



Note: — Small $s_g = \tau^D$ — Benchmark — Large $s_g = \tau^D$

Figure 7: Impulse responses to *foreign price shock*; money supply rule



Note: — Small $s_g = \tau^D$ — Benchmark — Large $s_g = \tau^D$