Fiscal Stabilization in a Small Open Economy[a]

Bernhard Herz[b]

University of Bayreuth

Werner Roeger

European Commission, DG Economic and Financial Affairs

Lukas Vogel

University of Bayreuth

Abstract

The creation of EMU has revived the debate about the importance of asymmetric shocks and the consequences for stabilization policy inside a monetary union. In this context, the paper discusses fiscal stabilization at the national level. We analyze the demand- and supply-side effects of taxation and government spending in a small open economy model with infinite planning horizons. We consider optimal policy and the stabilizing potential of simple rules. Expenditure policies perform similar to monetary policy in stabilizing aggregate demand and cost-push shocks, whereas state-dependent taxation is a rather efficient tool to stabilize cost-push disturbances in the commitment case.

JEL classification: E 37, E 62, F 41

Keywords: Fiscal policy, macroeconomic stabilization, small open economy

---

[a] The views expressed in this paper are those of the authors only. We thank participants at the Euroframe conference, the Verein für Socialpolitik annual meeting, the MEDEE conference, and especially Florence Huart and Eric Mayer for helpful comments on an earlier version.
[b] Corresponding author: Bernhard Herz, VWL 1, Economics Department, University of Bayreuth, D-95440 Bayreuth, Germany. Tel.: +49.921.55.2912. Fax: +49.921.55.2949. Email: bernhard.herz@uni-bayreuth.de.

1. Introduction

As countries enter currency unions or fixed exchange rate regimes they give up their monetary independence. The costs of abandoning the monetary policy instrument are particularly high in the presence of asymmetric shocks and differences in the monetary policy transmission as has been comprehensively discussed in the context of the European Monetary Union. Thus, a monetary union makes greater demands on national fiscal policy as a tool of macroeconomic stabilization. The ongoing discussions on the Stability and Growth Pact which restricts national fiscal policy could be interpreted as the attempt of governments to regain fiscal policy independence and increase the scope of their stabilization policy. Empirically, the output volatility in the EMU has not declined after 1999 with the deviation from average being largest for the small EMU economies.

The issue of fiscal stabilization in monetary union has attracted considerable interest. Most contributions, e.g. Bofinger and Mayer (2004) and Van Aarle et al. (2004), consider the primary budget balance as the fiscal instrument and discuss monetary and fiscal policy interaction in the Euro area. Beetsma and Jensen (2002, 2004), and Galí and Monacelli (2004) analyze optimal government spending in a micro-founded New Keynesian model. The present paper is in line with this research. It uses a more general setting and a larger set of policy variables than Beetsma and Jensen (2002, 2004), and Galí and Monacelli (2004), however.

The paper discusses the short-term stabilizing potential of fiscal policy. In contrast to much of the literature we do not focus on the overall budget, but consider tax rates and public expenditure separately. We investigate whether state-dependent tax and expenditure policies can contribute to business-cycle stabilization. We restrict attention to consumption and labor income taxation and to government consumption. We motivate our disaggregated perspective on fiscal policy by the fact that both a micro-founded model and empirical studies find differences in the impact of direct and indirect taxation and of public expenditure on aggregate demand and supply. Mountford and Uhlig (2002) find that deficit-financed tax reductions are more effective in dampening fluctuations than deficit- or tax-financed expenditure increases. Wijkander and Roeger (2002) suggest that variations in government spending, government employment and consumption taxes have relatively strong aggregate demand effects.

The paper examines the stabilizing potential of fiscal instruments in a small and purely forward-looking New Keynesian model that is a standard tool in monetary policy research. We build on the approach of Clarida et al. (2001), and Galí and Monacelli (2002, 2004) and restrict attention to the small open economy case. In order to examine fiscal stabilization, we derive the demand- and supply-side effects of consumption and labor income taxation, and of government spending. We consider optimal policy under discretion and commitment and a simple rule, and compare the results to monetary business-cycle stabilization. Our discussion treats fiscal policy as an endogenous variable and not, as in the conventional analysis of (monetary) stabilization policy, as an exogenous shock. Different from previous research (e.g., Beetsma and Jensen, 2002, Galí and Monacelli, 2004) we account for a lag in the implementation of fiscal measures.

The following section introduces fiscal policy in a New Keynesian small open economy model. We derive the equations for the output gap and inflation and discuss the conduct of fiscal policy. Section three analyses optimal policy and the performance of simple rules. Section four summarizes the main findings and concludes.

2. Model

This section incorporates fiscal policy in a dynamic small open economy model with intertemporal optimization. The aim is to investigate its short-term stabilizing potential with monetary policy set by a supranational central bank. The discussion builds on Clarida et al.

(2001), and Galí and Monacelli (2002). It simplifies the latter contributions by restricting attention to countries within a monetary union. In such a setting, we do not have to account for changes in the nominal exchange rate and their impact on the terms of trade. On the other hand, we extend the specification by including distortionary taxation and government spending. Our policy variables are state-dependent adjustments in consumption and income taxes and in government spending.

2.1 Private households

Household utility is given as the discounted stream of utility

(1) $$U = E_t \sum_{i=0}^{\infty} \beta^i U_{t+i} \ ,$$

with β as the discount factor.

Household utility is a function of household consumption and leisure. Overall utility is additive in the utility of consumption and the disutility of working. We have

(2) $$U_t(C_t, N_t) = \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{\vartheta}{1+\phi} N_t^{1+\phi},$$

where C is consumption, N is the working time, ϑ quantifies the relative weight of foregone leisure, σ is the coefficient of risk aversion - the inverse of the inter-temporal elasticity of substitution - and ϕ is the inverse of the elasticity of labor supply.

The model combines a competitive labor market with monopolistic competition in the goods market. Households consume domestic and foreign commodities according to a CES utility function (see Galí and Monacelli, 2002)

(3) $$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}},$$

with C_H and C_F as aggregates of domestic and imported goods and services, respectively, and η as the elasticity of substitution between C_H and C_F. The optimal allocation of expenditure between domestic and imported commodities implies

$$(4) \qquad C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \; ; \qquad C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t .$$

Inserting (4) in (3) gives the price of the bundle of consumer goods as

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

If the price level of domestic and imported goods is the same, $P_{H,t} = P_{F,t}$, α corresponds to the share of imports in domestic consumption. Thus, the parameter α is the equilibrium share of imports in domestic household consumption, i.e. trade openness in the steady state.

The indices of domestic and foreign goods are CES aggregates of the quantities consumed of each variety

$$(5) \qquad C_{H,t} = \left(\int_0^1 C_{h,t}{}^{\frac{\varepsilon-1}{\varepsilon}} dh\right)^{\frac{\varepsilon}{\varepsilon-1}}, \qquad C_{F,t} = \left(\int_0^1 C_{f,t}{}^{\frac{\varepsilon-1}{\varepsilon}} df\right)^{\frac{\varepsilon}{\varepsilon-1}},$$

with ε as the elasticity of substitution between differentiated goods in each category. The optimal allocation of resources to each commodity *h* and *f* satisfies

$$(6) \qquad C_{h,t} = (1-\alpha)\left(\frac{P_{h,t}}{P_{H,t}}\right)^{-\varepsilon} C_{H,t} \; ; \quad C_{f,t} = \alpha\left(\frac{P_{f,t}}{P_{F,t}}\right)^{-\varepsilon} C_{F,t} .$$

Inserting both expressions in (5) gives the price level of domestic and foreign goods as

$$P_{H,t} = \left(\int_0^1 P_{h,t}{}^{\varepsilon-1} dh\right)^{\frac{1}{1-\varepsilon}}, \qquad P_{F,t} = \left(\int_0^1 P_{f,t}{}^{\varepsilon-1} df\right)^{\frac{1}{1-\varepsilon}} .$$

Private households have full access to asset markets and can diversify risk. The representative household's flow budget constraint is

$$(7) \qquad (1-\iota_t)W_t N_t + D_t + T_t = (1+\tau_t)P_t C_t + B_{t+1} - (1+i_t)B_t .$$

W_t is the nominal wage per unit of labor and ι the tax on labor income. D_t are nominal profit from firm ownership, whereas T_t are net lump-sum transfers from the government to the private households. The nominal expenditure on consumption is $(1+\tau_t)P_t C_t$. It is composed of the spending on domestic goods $(1+\tau_t)P_{H,t}C_{H,t}$ and the spending on foreign commodities $(1+\tau_t)P_{F,t}C_{F,t}$. The expression $B_{t+1}-(1+i_t)B_t$ gives the investment in risk-free one-period bonds in period t. Note that in order to limit the complexity of the model, capital is excluded as a factor of production and as an opportunity for investment.

The representative household maximizes utility according to (1) and (2) under the budget constraint (7). With $\hat{x}_t = \ln X_t - \ln \overline{X}$ as the percentage deviation of variable X_t from its steady state $\overline{X}$, we obtain

$$(8) \qquad \hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma}\left(i_t + \frac{\overline{\tau}}{1+\overline{\tau}}\left[\hat{\tau}_t - E_t \hat{\tau}_{t+1}\right] - E_t \hat{\pi}_{t+1} - \overline{r} \right)$$

as the optimal path for consumption, and

$$(9) \qquad \hat{w}_t - \frac{\overline{\iota}}{1-\overline{\iota}}\hat{\iota}_t - \frac{\overline{\tau}}{1+\overline{\tau}}\hat{\tau}_t - \hat{p}_t = \phi \hat{n}_t + \sigma \hat{c}_t + \hat{\vartheta}$$

as the labor supply of optimizing households.[1] The higher the tax rates on income and consumption, the lower are the real wage, the opportunity costs of leisure, and labor supply.

2.2 Government sector

Government consumption is denoted as G_t. We assume that the government only consumes domestically produced commodities. Analogously to the behavior of private households, we assume that government consumption follows a CES function

[1] A more detailed derivation of the model equation can be found in the working paper version of the paper.

$$G_t = \left(\int_0^1 G_{h,t}^{\frac{\varepsilon-1}{\varepsilon}} dh \right)^{\frac{\varepsilon}{\varepsilon-1}}.$$

The optimal allocation of public sector demand on commodities h is thus

$$(10) \qquad G_{h,t} = \left(\frac{P_{h,t}}{P_{H,t}} \right)^{-\varepsilon} G_t .$$

The government makes net lump-sum transfers T_t to households, taxes private consumption and labor income and issues one-period bonds to finance public expenditure. Its budget constraint in nominal terms is

(11) $\quad P_{H,t}G_t + T_t = \iota_t W_t N_t + \tau_t P_t C_t + B_{t+1} - (1+i_t)B_t$. We impose the transversality condition $\lim_{t\to\infty} B_t = 0$. It implies that the government cannot run Ponzi schemes, and that private households do not waste part of their wealth. Fiscal policy is Ricardian in the sense that the government has to respect its budget constraint and that, eventually, all public debt must be repaid. Combining (11) with the private-sector constraint (7) gives the economy's overall resource constraint

$$(12) \qquad W_t N_t + D_t = P_t C_t + P_{H,t} G_t .$$

The transversality condition implies that tax receipts are either spent or returned to households as lump-sum transfers. If lump-sum transfers compensate for an increase in income or consumption taxes, the household income remains unchanged. If a tax rise leads to higher government consumption, on the other hand, private wealth declines.

2.3 The demand side

Nominal demand for domestic commodities in t is $P_{H,t}Y_t = P_{H,t}C_{H,t} + P_{H,t}C^*_{H,t} + P_{H,t}G_t$. The real aggregate demand for domestic goods and services

(13) $Y_t = C_{H,t} + C^*_{H,t} + G_t$

follows from dividing the nominal demand by the price level of domestically produced commodities. The log-linear approximation of equation (13) around the steady state is

(14) $\hat{y}_t = c_Y(1-\alpha)\hat{c}_{H,t} + c_Y\alpha\hat{c}^*_{H,t} + g_Y\hat{g}_t$,

where the steady-state share of consumer goods in aggregate demand, c_Y , combines the share of domestic household demand, $c_Y(1-\alpha)$, and the share of exports in overall demand, $c_Y\alpha$.

Inserting the optimum conditions for domestic- and foreign-household consumption, we obtain the inter-temporal output equation

(15) $$\hat{y}_t = \begin{pmatrix} E_t\hat{y}_{t+1} - c_Y\dfrac{\omega_\alpha}{\sigma}\left(i_t - E_t\hat{\pi}_{H,t+1} - \bar{r}\right) - c_Y\dfrac{1-\alpha}{\sigma}\dfrac{\bar{\tau}}{1+\bar{\tau}}\left(\hat{\tau}_t - E_t\hat{\tau}_{t+1}\right) + g_Y\left(\hat{g}_t - E_t\hat{g}_{t+1}\right) \\ + c_Y\dfrac{1-\alpha-\omega_\alpha}{\sigma}\dfrac{\bar{\tau}^*}{1+\bar{\tau}^*}\left(\hat{\tau}^*_t - E_t\hat{\tau}^*_{t+1}\right) + c_Y\left(\omega_\alpha - 1\right)\left(E_t\hat{c}^*_{t+1} - \hat{c}^*_t\right) \end{pmatrix}$$

with $\omega_\alpha = 1 + \alpha(2-\alpha)(\eta\sigma - 1)$. The variable $\hat{y}_t$ can be interpreted as the percentage deviation of output from the *no-shock* steady state.

2.4 The supply side

Firms produce output with constant returns to scale and labor as the only factor of production. Each firm produces $Y_{h,t} = A_t N_{h,t}$. The first-order approximation to the aggregate production function (see Galí and Monacelli 2002) is

(16) $\hat{y}_t = \hat{a}_t + \hat{n}_t$.

The model assumes monopolistic competition in the goods market. We adopt the Calvo model of staggered price setting. This model gives the New Keynesian Phillips curve

(17) $\hat{\pi}_{H,t} = \beta E_t\hat{\pi}_{H,t+1} + \kappa\hat{m}c_t$

as an equation for the forward-looking inflation dynamics, with $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ and with $1-\theta$ as the share of firms resetting prices in period t.

Combining the equation (17) with real marginal costs

$$mc_t = w_t - p_{H,t} - a_t$$

and the labor supply and demand conditions, we obtain the deviation of marginal costs from the steady state as

$$(18) \qquad \hat{m}c_t = \begin{pmatrix} \left(\phi + \frac{\sigma}{c_Y \omega_\alpha}\right)\hat{y}_t - \frac{g_Y \sigma}{c_Y \omega_\alpha}\hat{g}_t + \frac{1-\alpha}{\omega_\alpha}\frac{\bar{\tau}}{1+\bar{\tau}}\hat{\tau}_t + \frac{\bar{\imath}}{1-\bar{\imath}}\hat{\imath}_t + \hat{\ln}\,\vartheta \\ -(1+\phi)\hat{a}_t + \left(1 - \frac{1-\alpha}{\omega_\alpha}\right)\frac{\bar{\tau}^*}{1+\bar{\tau}^*}\hat{\tau}_t^* + \sigma\left(1 - \frac{1}{\omega_\alpha}\right)\left(\frac{\hat{y}_t^*}{c_Y^*} - \frac{g_Y^* \hat{g}_t^*}{c_Y^*}\right) \end{pmatrix},$$

with $\omega_\alpha = 1 + \alpha(2-\alpha)(\eta\sigma - 1)$.

2.5 Inflation and the output gap

The output gap $\hat{x}_t = \hat{y}_t - \hat{y}_t^f$ indicates the percentage deviation of output from its natural level. We define the latter as the equilibrium level in the absence of nominal rigidities, with steady-state fiscal policy and conditional on foreign demand for domestic goods. With flexible prices each firm adjusts its price in every period and charges a constant mark-up. Real marginal costs do not fluctuate in this case, so that $m\hat{c}_t^f = 0$. If we consider taxation and government spending as our policy tools that are only adjusted in the case of non-zero output gaps, we can assume $\hat{g}_t^f = \hat{\tau}_t^f = \hat{\imath}_t^f = 0$ and write equation (18) as

$$\hat{m}c_t = \left(\phi + \frac{\sigma}{c_Y \omega_\alpha}\right)\hat{x}_t - \frac{g_Y \sigma}{c_Y \omega_\alpha}\hat{g}_t + \frac{1-\alpha}{\omega_\alpha}\frac{\bar{\tau}}{1+\bar{\tau}}\hat{\tau} + \frac{\bar{\imath}}{1-\bar{\imath}}\hat{\imath}\ .$$

Combining the equation with (17) gives an augmented New Keynesian Phillips curve

$$(19)\qquad \hat{\pi}_{H,t} = \beta E_t \hat{\pi}_{H,t+1} + \kappa \left(\left[\phi + \frac{\sigma}{c_Y \omega_\alpha} \right] \hat{x}_t - \frac{g_Y \sigma}{c_Y \omega_\alpha} \hat{g}_t + \frac{1-\alpha}{\omega_\alpha} \frac{\bar{\tau}}{1+\bar{\tau}} \hat{\tau}_t + \frac{\bar{\iota}}{1-\bar{\iota}} \hat{\iota}_t \right),$$

which accounts for the impact of the output gap and of the supply-side channel of fiscal policy on inflation.

Similarly, we can rewrite the inter-temporal aggregate demand equation in terms of the output gap. We solve (15) for $\hat{y}_t^f$ and assume that policy is inactive in the flexible-price equilibrium case, i.e. $\hat{g}^f = \hat{\tau}^f = \hat{\iota}^f = 0$. The we subtract the flexible price solution from the general case in equation (15). The dynamic equation for the output gap results as

$$(20)\qquad \hat{x}_t = E_t \hat{x}_{t+1} - c_Y \frac{\omega_\alpha}{\sigma} \left(i_t - E_t \hat{\pi}_{H,t+1} - \bar{r}_t \right) - c_Y \frac{1-\alpha}{\sigma} \frac{\bar{\tau}}{1+\bar{\tau}} \left(\hat{\tau}_t - E_t \hat{\tau}_{t+1} \right) + g_Y \left(\hat{g}_t - E_t \hat{g}_{t+1} \right).$$

The variable $\bar{r}_t$ is the equilibrium real interest rate conditional on foreign demand, technology and changes in household behavior. It equals

$$(21)\qquad \bar{r}_t = \begin{pmatrix} \bar{r} + \sigma \dfrac{1+\phi}{c_Y \omega_\alpha \phi + \sigma} E_t \Delta a_{t+1} - \dfrac{\sigma}{c_Y \omega_\alpha \phi + \sigma} E_t \Delta \ln \vartheta_{t+1} \\ - c_Y \phi \sigma \dfrac{1-\omega_\alpha}{c_Y \omega_\alpha \phi + \sigma} E_t \Delta c_{t+1}^* - c_Y \phi \dfrac{1-\alpha-\omega_\alpha}{c_Y \omega_\alpha \phi + \sigma} \dfrac{\bar{\tau}^*}{1+\bar{\tau}^*} E_t \Delta \hat{\tau}_{t+1}^* \end{pmatrix}.$$

The Phillips curve (19) and the output equation (20) describe the dynamics of domestic goods prices (net of consumption taxes) and of the output gap in a small open economy with inter-temporal optimization and with nominal rigidities. Fiscal policy affects both the supply and the demand side. The supply-side effects result from the impact of taxation and public expenditure on labor supply. The taxation of consumption and of labor income reduces the real wage, i.e. the opportunity cost of leisure. Labor supply declines and marginal costs increase as a result. An increase in government expenditure conversely reduces marginal costs and inflationary pressures. This is because the increase in public consumption reduces private wealth and life-time household consumption. The marginal utility is decreasing in the level of consumption. A reduction in private wealth therefore causes the labor supply of households to increase. Real wages and marginal costs decrease for a given level of production.

The demand-side effects of fiscal policy rest upon government expenditure and consumption taxes. Government expenditure is a component of aggregate demand (13). A reduction in public spending lowers the output gap. An increase in government expenditure, on the other hand, also increases the output gap. Consumption taxes operate through their impact on private consumption. If the present tax rate exceeds the expected future rate, optimizing households will reduce current consumption in exchange for higher future demand. If the consumption tax is expected to rise in the future, households will substitute future for present consumption. The effect of an expected change in the sales tax is thus similar to the impact of changes in the real interest rate in the IS equation. The effect on private consumption positively depends on the inter-temporal elasticity of substitution. The impact on domestic aggregate demand furthermore depends on the equilibrium share of domestic commodities in private domestic consumption.

2.6 Fiscal policy

We now turn to the potential for state-dependent tax and spending policies to dampen cyclical fluctuations. The government conducts fiscal policy following a loss function. As shown by Galí and Monacelli (2002), and Woodford (2003), the loss function can be seen as a quadratic approximation of the household utility function around the steady state. We consider

$$(22) \qquad L = E_t\left[\sum_{i=0}^{\infty}\beta^i\left(q_x\hat{x}_{t+i}^2 + q_\pi\hat{\pi}_{t+i}^2 + q_f\, f_t^{\,2}\right)\right],$$

with $q_f = (q_\tau, q_\iota, q_g)$ and f_t as the vector of policy instruments, i.e. state-dependent sales and income taxes and government spending. The weights attached to output, inflation and policy intervention are q_x, q_π and q_f, respectively. We set $f_t = (\Delta\tau_{t+1}, \Delta\iota_{t+1}, \Delta g_{t+1})'$, so that q_f measures the costs of *percentage-point* changes in the instrument.[2]

A prominent objection against the use of fiscal policy for short-term stabilization is its long implementation lag (*inside lag*). The impact lag (*outside lag*) of fiscal measures seems rather modest, on the other hand (e.g., Blinder, 2004). We differ from previous work (e.g., Beetsma and Jensen 2002, 2004, Galí and Monacelli, 2004) and account for an inside lag, i.e. we distinguish between the *announcement* and the *implementation* of fiscal measures. Here we assume a lag of one period, so that current measures equal the policy that has been announced in the previous period. As a consequence, tax rates and levels of public spending are predetermined in period *t*. Referring to $(\Delta\tau_t^a, \Delta\iota_t^a, \Delta g_t^a)'$ as the announcement and to $(\Delta\tau_t, \Delta\iota_t, \Delta g_t)'$ as the implemented policy we have $(\Delta\tau_t, \Delta\iota_t, \Delta g_t)' = (\Delta\tau_{t-1}^a, \Delta\iota_{t-1}^a, \Delta g_{t-1}^a)'$.

It is important to note that the implementation lag does not impair the stabilizing potential of fiscal policy. A credible announcement to react to contemporaneous output and inflation will affect the optimizing behavior of private households. Fiscal policy affects the inter-temporal allocation of consumption and leisure, which depends on the expected changes in taxation and government spending. Expected changes in the sales tax alter the expected real interest rate and impact on the saving-spending decision of optimizing households, whereas the tax on income affects nominal wages and the inter-temporal labor supply.

In our model of Ricardian households, the distinction between the announcement and the implementation of policies has two interesting implications. The first implication is that

[2] Penalizing percentage changes of the instrument requires setting $f_t = (\Delta\hat{\tau}_{t+1}, \Delta\hat{\iota}_{t+1}, \Delta\hat{g}_{t+1})'$. Given that $\Delta\hat{\tau}_{t+1} \approx (\tau_{t+1} - \tau_t)/\bar{\tau}$ we can approximate the difference between *percentage-point* and *percentage* changes as $\Delta\tau_{t+1} = \tau_{t+1} - \tau_t \approx \Delta\hat{\tau}_{t+1}\bar{\tau}$. The same applies to changes in income tax rates and government spending.

inter-temporal optimization mitigates the problem of the inside lag for fiscal stabilization. IT is the credible announcement that affects the decisions of the private sector. The inter-temporal substitution depends on the expected changes in distortionary taxes and public spending, which follows from an instrument adjustment either in period *t* or in period *t+1*. Consequently, the inside lag does not impair fiscal stabilization. The conclusion is conditional on unconstrained inter-temporal optimization. Specifically, our model does not include liquidity constraints, or rule-of-thumb consumers (e.g., Galí et al., 2004).

The second consequence of the inside lag is a potential time-consistency problem. The private households choose consumption and leisure conditional on the expected policy. If the government's announcement lacks credibility, state-dependent policy will have little stabilizing effects. Therefore, the authority needs to ensure that the implementation corresponds to the announced policy measures. The inside lag, itself, is a possible solution to the time-consistency problem. Technical or administrative constraints delay the implementation of policy plans to the subsequent period. The inside lag delays the implementation, but, at the same time, it ensures that the government cannot deviate *ex post* from the announced policy.

With optimizing Ricardian households, distortionary taxation has only substitution effects, but no impact on disposable income. For simplicity, we assume lump-sum transfers to balance the government budget. Based on the substitution effects of distortionary taxation and government expenditure, fiscal stabilization is compatible with a balanced government budget. Public deficits and debt dynamics are then of secondary importance. They only become relevant if one relaxes the assumption of infinitely-lived households and allows for rule-of-thumb consumers, or finite planning horizons. In this case, state-dependent taxation does not only affect the opportunity costs of consumption and leisure, but also the currently disposable income of private households.

3. Simulation results

This section presents numerical simulations and impulse responses for optimal policy under discretion and under commitment, and for a simple rule. The equations (28) and (29) characterize the demand and supply side of the small open economy. Table 1 summarizes the calibration of the model parameters. A time period corresponds to a quarter of a year. For the smaller EMU countries, the overall share of consumption in GDP is about 0.55 and the GDP share of government consumption about 0.20. As we do not distinguish between consumption and investment expenditure, we scale the private and government consumption shares so that they add up to one. The ratio of exports to GDP is about 0.55 (see European Commission, 2003). We take the average VAT and labor income tax rate for the small EMU economies in 2003 to proxy the steady state level of indirect and direct taxation.[3] The data are from OECD (2004) and show an average income tax rate of 26% and an average VAT rate of 20%. For the remaining parameters we rely on standard values. Common choices for the coefficient of risk aversion are 1 and 2 (see Clarida et al., 2000). Following Galí and Monacelli (2002) we calibrate the inverse of the elasticity of labor supply as $\phi = 1.5$ and set the elasticity of substitution between domestic and foreign commodities to one. The value $\theta = 0.75$ for the probability of price non-adjustment implies an average contract length of one year, which matches empirical observations (see Taylor, 1998). Together with the discount factor $\beta = 0.99$ we obtain $\kappa = 0.086$ for the sensitivity of inflation to marginal costs. This value is very close to the estimate of 0.09 for EMU countries in Galí et al. (2001).

*****Table 1 about here*****

The calibrated inter-temporal demand and New Keynesian Phillips curve equations are thus

[3] The values for economic openness, the GDP shares of private and public consumption and the average consumption and income taxes are non-weighted averages for Austria, Belgium, Greece, Finland, Ireland, the Netherlands and Portugal.

$$\hat{x}_t = E_t\hat{x}_{t+1} + 0.73E_t\hat{\pi}_{H,t+1} + 0.05\left(E_t\hat{\tau}_{t+1} - \hat{\tau}_t\right) - 0.27\left(E_t\hat{g}_{t+1} - \hat{g}_t\right) + \varepsilon_{x,t} ,$$

$$\hat{\pi}_{H,t} = 0.99E_t\hat{\pi}_{H,t+1} + 0.26\hat{x}_t - 0.03\hat{g}_t + 0.01\hat{\tau}_t + 0.03\hat{\iota}_t + \varepsilon_{\pi,t} ,$$

with $\varepsilon_{\pi,t}$ as exogenous cost-push shock and

$$\varepsilon_{x,t} = 0.73\begin{pmatrix} -i_t + \bar{r} + \sigma\dfrac{1+\phi}{c_Y\omega_\alpha\phi + \sigma}E_t\Delta a_{t+1} - \dfrac{\sigma}{c_Y\omega_\alpha\phi + \sigma}E_t\Delta\ln\vartheta_{t+1} \\ -c_Y\phi\sigma\dfrac{1-\omega_\alpha}{c_Y\omega_\alpha\phi + \sigma}E_t\Delta c^*_{t+1} - c_Y\phi\dfrac{1-\alpha-\omega_\alpha}{c_Y\omega_\alpha\phi + \sigma}\dfrac{\bar{\tau}^*}{1+\bar{\tau}^*}E_t\Delta\hat{\tau}^*_{t+1} \end{pmatrix}$$

as an aggregated demand shock. Assuming shock persistence, we specify the AR(1) processes $\varepsilon_{x,t} = \rho_x\varepsilon_{x,t-1} + \hat{\varepsilon}_{x,t}$ and $\varepsilon_{\pi,t} = \rho_\pi\varepsilon_{\pi,t-1} + \hat{\varepsilon}_{\pi,t}$ with $\rho_x = \rho_\pi = 0.5$.[4]

We solve the model under rational expectations, using the algorithms of Söderlind (1999). Because of the inside lag, tax rates and public expenditure levels are predetermined in *t*. The announced policies are implemented with a one-period delay.

3.1 Optimal policy under discretion

The loss function combined with our model structure allows deriving the optimal fiscal responses to aggregate demand and cost-push shocks. The following subsections present impulse responses for the unrestricted optimization, where policy is not bound to a specific instrument rule. In a first step, we consider optimal discretionary stabilization. The meaning of discretionary policy may need clarification in our context. We have stressed above that policy effectiveness depends on the credible implementation of the announced measures, and that the implementation lag may ensure this credibility. Usually, discretionary policy refers to the idea that the credible implementation is not feasible (e.g., Beetsma and Jensen, 2002, Galí and

[4] To limit our discussion, we only display results for this intermediate degree of shock persistence. It is perfectly feasible to generate impulse responses for higher degrees of shock persistence, however.

Monacelli, 2004). In our case, however, discretionary policy only refers to the situation, where the fiscal policy cannot credibly commit to the announcement of specific policy measures in subsequent periods. The time inconsistency does, in other words, not undermine the implementation of current announcements. It only rules out that policy credibly commits to specific announcements for the subsequent periods. Consequently, discretionary optimisation does not affect the private sector's expectations beyond the period $t+1$, the period in which the current announcement is going to be implemented.

The figures 1 and 2 depict the optimal discretionary response to a unit demand and a unit cost-push shock, respectively. We set the cost of policy intervention equal to 0.5, i.e. $q_f = 0.5$. The weights of deviations of output and inflation are set to $q_x = q_\pi = 1.0$. We compare the stabilizing potential of state-dependent fiscal policy with monetary stabilization. Except for the inclusion of the fiscal instruments, the equations (28) and (29) correspond to the IS and Phillips curve equations in Galí and Monacelli (2002), i.e. in a small open economy with flexible exchange rates. Thus, the interest rate reaction in the subsequent figures characterizes optimal monetary policy under flexible exchanges rates and without fiscal intervention. The calibration of the model with monetary policy corresponds to table 1.

*****Figure 1 about here*****

Figure 1 shows the optimal response to a persistent unit demand shock in period one. Monetary policy and government expenditure perform similarly. They outperform the state-dependent adjustment of income and sales taxes. Given the announced rise in *public spending*, households expect output and inflation to increase in period *t+1*. The increase in expected inflation lowers the *ex ante* real interest rate, so that households partially substitute future consumption for present expenditure. Given the government budget constraint, the expected increase in public expenditure also reduces private wealth. The resulting decrease in life-time consumption is partly offset by an increase in labor supply. This increase in labor supply mitigates the inflationary impact of higher output.

The announced reduction of the *sales tax* in figure 1 affects aggregate demand via the inter-temporal substitution effect. Because taxes will be lower in the future, the private households partly postpone consumption to subsequent periods, which dampens current aggregate demand and current inflation. On the supply side, the announcement increases the opportunity costs of leisure and the labor supply. For our calibration, the positive impact of higher demand in *t+1* on future inflation dominates the anti-inflationary impact of higher real wage on the labor supply. Consequently, the real interest rate falls and partly offsets the inter-temporal substitution of consumption induced by the VAT cut.

The discretionary adjustment of the *labor-income tax* does hardly stabilize the demand shock in figure 1. In the Ricardian framework, the income tax affects the marginal costs of production and inflation, but has no direct impact on the real interest rate and on permanent income. A rise in the income tax reduces the future net wage and leads to an inter-temporal substitution of labor supply. The current labor supply increases and stabilizes current inflation, whereas the labor supply in *t+1* declines. The decline in future working hours increases future inflation and lowers the real interest rate. Consequently, private households substitute some future expenditure for present consumption, which increases the current output gap.

*****Figure 2 about here*****

Figure 2 displays the optimal response to a unit cost-push shock in period one. As the demand shock (see table 1), optimal government spending performs similar to monetary stabilization. State dependent consumption and income taxes are less stabilizing for the given penalization of policy activism ($q_f = 0.5$), however.

The announced increase in *government spending* from period *t* to *t+1* increases expected inflation, which adds to the decline of the expected real rate following the persistent cost shock. As a consequence, private households substitute future for present consumption. The supply-side effect of higher public spending is a decline in private wealth and an increases the labor supply. The increase in labor supply dampens inflation, without fully compensating the demand-driven increase in current marginal costs.

The *tax rate on private consumption* is announced to fall in period *t+1*, so that households substitute present expenditure for future consumption. The supply effect of the VAT reduction is an increase in the real wage and in the labor supply. The positive supply effect mitigates the impact of future output gaps on expected inflation. The increase in labor supply raises the real interest rate and supports the inter-temporal substitution effect of the tax cut.

The state-dependent *taxation of labor income* can, in principle, stabilize output and inflation simultaneously. The announced increase in the tax rate triggers a decline in future net wages and the inter-temporal substitution of labor supply. Private households reduce future working hours and work more today. The increase in current labor supply reduces current marginal costs and stabilizes the cost shock. The announced tax rise furthermore increases the expected inflation and reduces the *ex ante* real interest rate. Consequently, private households substitute future for present consumption. Contrary to monetary policy, the state-dependent taxation of labor income does not require the policy maker to contract output in order to reduce inflation, i.e. there is no inflation-output tradeoff in the event of cost-push distortions. Given the relatively high costs of policy intervention in our loss function, the tax adjustment is too weak to achieve a substantial stabilization of the cost shock, however.

*****Figure 3 about here*****

The stabilizing impact of state-dependent consumption and income taxes on output and inflation increases when we allow for a stronger adjustment of the two policy instruments. The latter corresponds to lowering the cost of policy interventions in the loss function compared to our example above. The figures 3 and 4 display the impulse responses for the extreme of costless policy intervention, i.e. for $q_f = 0$.

*****Figure 4 about here*****

As in the figures 1 and 2, public spending and monetary policy perform similarly and imply a quantitatively similar reaction to both shocks. The state-dependent VAT adjustment achieves a perfect stabilization of output for both demand and supply disturbances. The state dependent income tax, on the other hand, perfectly stabilizes the cost shock. It also achieves perfect inflation stabilization under the demand shock, whereas some output volatility remains in the latter case. Achieving this high degree of output and inflation stabilization requires a heavy adjustment of income tax and the consumption tax rates, however.

3.2 Optimal policy under commitment

The optimal commitment solution refers to the case, where the fiscal authority can credibly commit to implement the optimal policy at any time. Fiscal policy consequently affects the expectations of the private sector with respect to future output and inflation. The figures 5 and 6 display the impulse responses for $q_x = q_\pi = 1.0$ and $q_f = 0.5$.

*****Figure 5 about here*****

Under commitment, policy does not need to react as strongly than in the case of discretion. Both fiscal and monetary policy achieve a better stabilization of output and inflation with much lower policy interventions. State-dependent *public spending* performs at least as good as monetary policy in stabilizing the persistent shock to aggregate demand (figure 5). Fluctuations in the output gap and inflation are higher for state-dependent *taxes* on consumption and labor income. Both instruments perform much better under commitment than under discretion, however. Contrary to the discretionary case, the optimal policy under commitment is to follow a path of declining income tax rates. The resulting increase in the labor supply reduces expected inflation and increases the real interest rate. Consequently, private households substitute current for future consumption, which stabilizes current output.

*****Figure 6 about here*****

Figure 6 plots the optimal stabilization of a persistent cost-push shock. *Government spending* outperforms monetary policy with respect to output stabilization and implies a similar fluctuation in the inflation rate. The cut in spending lowers future output and reduces expected inflation. Real interest rates increase, so that private households postpone consumption.

For *consumption taxes*, the optimal policy in reaction to the cost-push shock is to announce an increase in the tax rate. The expected tax rise increases present private consumption at the expense of future demand. Under the given calibration, the anti-inflationary impact of a lower output gaps dominates the cost-push effect of the declining labor supply. Expected inflation falls and increases the *ex ante* real interest rate. The inter-temporal substitution of consumption weakens the initial effect of increasing tax rates on private expenditure.

The volatility of inflation is lowest for the state-dependent *income tax*. The optimal policy consists in raising the tax rates in future periods. This implies a decline in future net wages and the inter-temporal substitution of future for present labor supply, which dampens current inflation. The decline in net wages furthermore lowers the opportunity costs of leisure, which reduces private consumption.

3.3 Commitment to simple rules

This subsection finally considers simple fiscal policy rules as an alternative to the unrestricted optimization. Stabilization policy may benefit from the commitment to a simple rule to overcome the credibility problems. Simple rules are relatively simple to understand, and they are transparent. The commitment to a simple rule is therefore easier, and easier to observe, than a commitment to the optimal policy (see Beetsma and Jensen, 2002).[5]

Research on monetary policy has investigated a variety of rules that differ with respect to the weights on output and inflation, the degree of forward- or backward-looking behavior, and the degree of instrument smoothing. To illustrate the performance of a simple fiscal rule that accounts for the inside lag of fiscal policy, we modify the proposal of Taylor (1993) to

(23) $$\Delta \tau_t^a = \psi_x \hat{x}_t + \psi_\pi \hat{\pi}_{H,t} .$$

We set $\psi_x = -0.5$ and $\psi_\pi -1.5$. This choice of policy parameters does not correspond to an optimal calibration for the different instruments. It just follows the Taylor (1993) proposal for monetary policy and only serves as an illustration. A positive output or inflation gap prompts a future decrease of the *consumption tax*, which induces an inter-temporal substitution of consumption. For *income taxation* and for government spending, we use $\Delta \iota_t^a = -0.5\hat{x}_t - 1.5\hat{\pi}_{H,t}$, and $\Delta g_t^a = 0.5\hat{x}_t + 1.5\hat{\pi}_{H,t}$. The fiscal authority announces a cut in *income taxes* in reaction to positive output and inflation gaps, whereas *public spending* is going to be reduced. Finally, we compare the performance with monetary stabilization in a small open economy with flexible exchange rates and the Taylor (1993) rule, i.e. $i_t = 0.5\hat{x}_t + 1.5\hat{\pi}_{H,t}$.

*****Figure 7 about here*****

The figures 7 and 8 display the stabilizing potential of the simple policy rule for persistent demand and cost push-shocks with AR(1) coefficients of 0.5, respectively. For each of the policy instruments, the simple rule ensures the stability and determinacy of our model (see Blanchard and Kahn, 1980, Juillard, 1999). The stabilizing potential lies somewhere in between the optimal commitment and the optimal discretionary solution. Given the high weight

[5] Additionally, the optimal policy is more demanding in terms of the required information about the economic structure and the nature of the shocks. Taylor (1999) and Levine et al. (1999) illustrate that policies, which are optimal in a specific environment, may perform badly in a modified model structure.

on inflation relative to the output gap, the simple rule achieves a high degree of inflation stabilization in case of demand disturbances. This comes at the cost of higher output volatility. The instrument path is less smooth than in the case of optimal commitment with costs of policy intervention.

*****Figure 8 about here*****

Similar conclusions apply to the stabilization of supply-side disturbances. The high weight on inflation leads to a volatility of output than under in the case of optimal commitment, where we put equal weight to output and inflation in the loss function. Note that the fiscal rule is equally successful than monetary policy in stabilizing the cost-push shock. Especially the state-dependent income tax apprears to outperform monetary stabilization in our example. The reason is that income taxation directly affects inflation through its impact on marginal costs, whereas it does not figure enter the aggregate demand equation. Consequently, the income tax adjustment does not face an output-inflation tradeoff.

Table 2 gives a broader characterization of the stabilizing potential of fiscal and monetary policy under the simple Taylor-type rule. The table displays the volatility of output and inflation and the magnitude of the instrument adjustment. The results are for aggregate demand and cost-push shocks of 0.5 standard deviations and different degrees of shock persistence. The table compares monetary policy in a small open economy under flexible exchange rates with fiscal stabilization in our fixed rate environment. The first column reports the standard deviation of output, inflation and the nominal interest rate. The other columns display the volatility of output, inflation and the fiscal instrument relative to monetary stabilization.

*****Table 2 about here*****

The results in table 2 suggest three main conclusions about the relative performance of monetary and fiscal policy under the simple Taylor-type rule. Firstly, the fiscal stabilization of output is weaker in the case of aggregate demand shocks, but stronger in case of supply-side distortions. Inflation volatility is, secondly, lower under fiscal stabilization in all cases. Thirdly, the Taylor-type rule that we have taken as an example requires more variation in the fiscal than in the monetary policy instrument, especially in reaction to highly persistent shocks.

4. Conclusions

This paper introduces fiscal policy in a micro-founded New Keynesian model of a small open economy in monetary union. We have considered three different fiscal instruments, government expenditure, a consumption and an income tax. Contrary to most New Keynesian monetary policy models, fiscal policy is not exogenous but endogenous in our setting. We take a disaggregated perspective, i.e. we consider various fiscal instruments instead of restricting the analysis to the budget surplus as an overall indicator for the fiscal stance. We prefer this disaggregated view to an overall indicator, because we expect that direct and indirect taxation and public spending affect the behavior of private households in different ways. The principal difference between monetary and fiscal policy in our framework is that the fiscal instruments have not only demand-side, but also supply-side effects. Consequently, they enter both the demand equation and the New Keynesian Phillips curve.

We have analyzed the optimal policy under discretion and under commitment and the performance of a simple Taylor-type rules. Thereby, we account for implementation lag in fiscal policy. We find that state-dependent expenditure policies perform similar to monetary policy under discretion and under commitment. They outperform the effectiveness of optimal tax policies in reaction to demand-side distortions. State-dependent is rather efficient however in stabilizing supply-side distortions in the commitment case. This particularly applies to the tax on labor income, which enters our model only via the Phillips curve equation. The stabilization of the business cycle is also compatible with public finance sustainability. Deficit neutrality does not impair fiscal stabilization when fiscal measures affect the behavior of private households via their substitution effects, and when the private sector is not credit constrained. For simplicity, we assume lump-sum transfers to balance the budget without impairing the substitution effects.

Our discussion rests on two strong assumptions. We assume Ricardian households and purely forward-looking inflation and output dynamics. We shall relax this assumption in subsequent work. A first step would be to replace Ricardian equivalence. One can proceed either by assuming finite planning horizons, or by considering a combination of inter-temporally optimizing households and rule-of-thumb consumers that spend their currently disposable income (see Mankiw, 2000, Galí et al., 2004). Consumption and income taxes do then not only affect the optimizing conditions, but also the disposable income of private households. In a second step one should discuss the stabilizing potential of state-dependent policy in a hybrid macro-model, i.e. in a model featuring forward- and backward-looking behavior.

An interesting extension is to consider the optimal combination of fiscal instruments. Instead of analyzing the relative performance of a single tool, the instruments can be combined in order to achieve an optimal degree of short-term stabilization. Subsequent work should further develop on the welfare implications of state-dependent taxation and government expenditure. Beetsma and Jensen (2002, 2004), and Galí and Monacelli (2004) provide a micro-funded loss-function for counter-cyclical government spending. Their discussion may be transferred to distortionary taxation. Extending the model to a two-country monetary union would allow to investigate potential externalities from fiscal policy and policy interactions.

References:

Beetsma, R. and H. Jensen (2002), 'Monetary and fiscal policy interactions in a micro-founded model of a monetary union', ECB Working Paper 166.

Beetsma, R. and H. Jensen (2004), 'Mark-up Fluctuations and Fiscal Policy Stabilization in a Monetary Union', *Journal of Macroeconomics* 66, 357-376.

Blanchard, O. and Ch. Kahn (1980), 'The Solution of Linear Difference Models under Rational Expectations', *Econometrica* 48, 1305-1311.

Blinder, A. (2004), 'The Case Against the Case Against Discretionary Fiscal Policy', CEPS Working Paper 100.

Bofinger, P. and E. Mayer (2004), 'Monetary and Fiscal Policy Interaction in the Euro Area with Different Assumptions on the Phillips Curve', CEPR Discussion Paper Series 4790.

Clarida, R., J. Galí and M. Gertler (1999), 'The Science of Monetary Policy: A New Keynesian Perspective', *Journal of Economic Literature* 37, 1661-1707.

Clarida, R., J. Galí and M. Gertler (2000), 'Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory', *Quarterly Journal of Economics* 105, 147-180.

Clarida, R., J. Galí and M. Gertler (2001), 'Optimal Monetary Policy in Open vs. Closed Economies: An Integrated Approach', *American Economic Review* 91, 248-252.

European Commission (2003), *European Economy: Statistical Annex*, Office for Official Publications of the EC, Luxemburg.

Galí, J. (2003), 'New Perspectives on Monetary Policy, Inflation, and the Business Cycle', in: M. Dewatripont, L. Hansen and S. Turnovsky (eds.), *Advances in Economics and Econometrics* Vol. 3, Cambridge University Press, Cambridge.

Galí, J. and R. Perotti (2003), ‘Fiscal policy and monetary integration in Europe’, *Economic Policy* 37, 535-572.

Galí, J. and T. Monacelli (2002), ‘Monetary policy and exchange rate volatility in a small open economy’, NBER Working Paper 8905.

Galí, J. and T. Monacelli (2004), ‘Optimal Fiscal Policy in a Monetary Union’, mimeo.

Galí, J., M. Gertler and D. Lopez-Salido (2001), ‘European inflation dynamics’, *European Economic Review* 45, 1237-1270.

Galí, J., D. Lopez-Salido and J. Vallés (2004), ‘Rule-of-Thumb Consumers and the Design of Interest Rate Rules’, NBER Working Paper 10392.

Juillard, M. (1999), ‘The Dynamic Analysis of Forward-Looking Models’, in: A. Hughes Hallett and P. McAdam (eds.), *Analyses in Macroeconomic Modeling*, Kluwer, Boston.

Levine, A., V. Wieland and J. Williams (1999), ‘Robustness of Simple Monetary Policy Rules under Model Uncertainty’, in: J. Taylor (ed.), *Monetary Policy Rules*, University of Chicago Press, Chicago.

Mankiw, G. (2000), ‘The Savers-Spenders Theory of Fiscal Policy’, *American Economic Review* 90, 120-125.

Mountford, A. and H. Uhlig (2002): ‘What are the effects of fiscal policy shocks?’, CEPR Discussion Paper Series 3338.

OECD (2004), *OECD Tax Database*, OECD, Paris.

Söderlind, P. (1999), ‘Solution and Estimation of RE Macro Models with Optimal Policy’, *European Economic Review* 43, 813-823.

Taylor, J. (1993), ‘Discretion versus policy rules in practice’, *Carnegie-Rochester Conference Series on Public Policy* 39, 195-214.

Taylor, J. (1998), ‘Staggered Price and Wage Setting in Macroeconomics’, NBER Working Paper 6754.

Van Aarle, B., H. Garretsen and F. Huart (2004): ‘Monetary and Fiscal Policy Rules in the EMU’, *German Economic Review* 5, 407-434.

Wijkander, H. and W. Roeger (2002), ‘Fiscal Policy in EMU: The Stabilization Aspect’, in: M. Buti, J. von Hagen and C. Martinez-Mongay (eds.), *The Behaviour of Fiscal Authorities,* Palgrave, Basingstoke.

Woodford, M. (2003), *Interest and Prices*, Princeton University Press, Princeton.

Appendices

A. Tables and figures

Parameter	Symbol	Value
Coefficient of risk aversion	σ	1.00
Consumption tax rate (steady state)	$\bar{\tau}$	0.20
Discount factor	β	0.99
Elasticity of labor supply	$1/\phi$	0.67
Elasticity of substitution between domestic and foreign goods	η	1.00
Exports to GDP (steady state)	α	0.55
Government consumption share in GDP (steady state)	g_Y	0.27
Income tax rate (steady state)	$\bar{\iota}$	0.26
Private consumption share in GDP (steady state)	c_Y	0.73
Sensitivity of inflation to marginal costs	κ	0.09

Table 1: Model calibration

Shock	AR (1)	Variable	Monetary policy σ_i	Public spending σ_g / σ_i	Consumption tax σ_τ / σ_i	Income tax σ_ι / σ_i
Demand shock	0.5	Output gap	0.47	1.45	1.51	1.57
		Inflation	0.24	0.92	0.92	0.83
		Instrument	0.59	1.90	1.95	1.27
	0.9	Output gap	0.76	4.28	3.99	4.06
		Inflation	1.81	0.63	0.67	0.57
		Instrument	3.10	2.33	3.49	1.73
Cost-push shock	0.5	Output gap	0.67	0.94	0.49	0.51
		Inflation	0.80	0.74	0.78	0.65
		Instrument	0.86	1.90	1.95	1.27
	0.9	Output gap	3.05	0.51	0.23	0.25
		Inflation	3.24	0.38	0.48	0.31
		Instrument	3.34	2.33	4.49	1.73

Table 2: Simple rule performance under demand and cost-push shocks

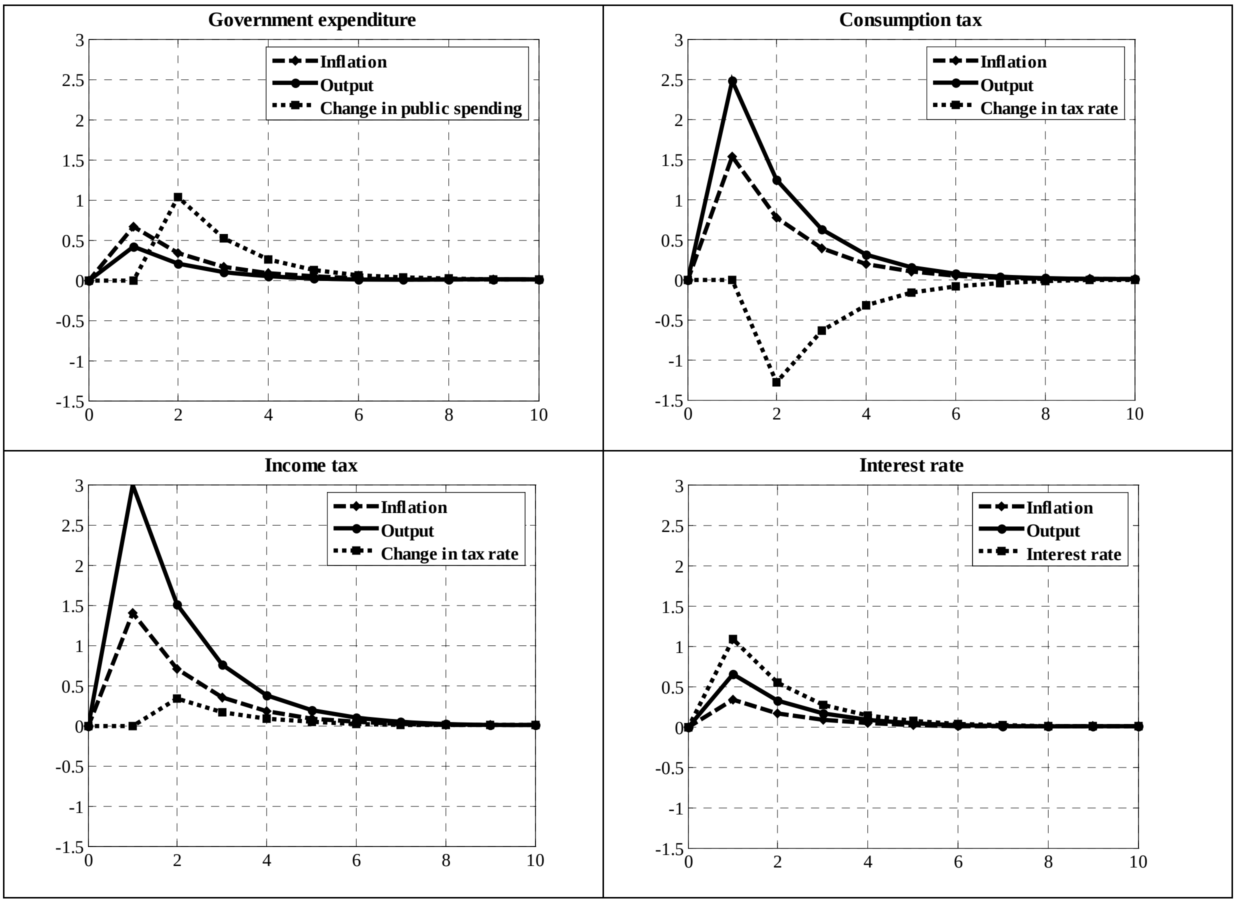

Figure 1: Optimal discretionary reaction to a unit demand shock

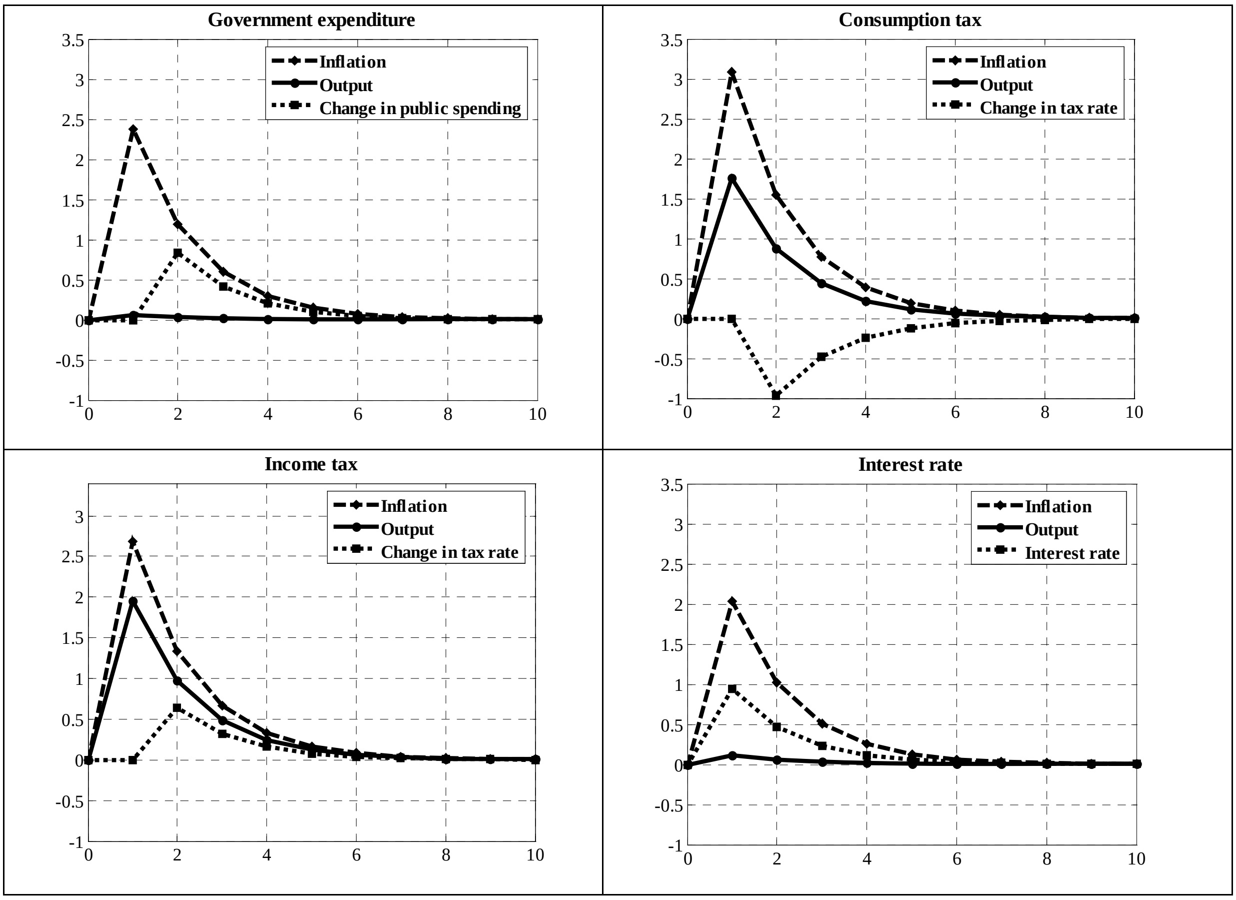

Figure 2: Optimal discretionary reaction to a unit cost-push shock

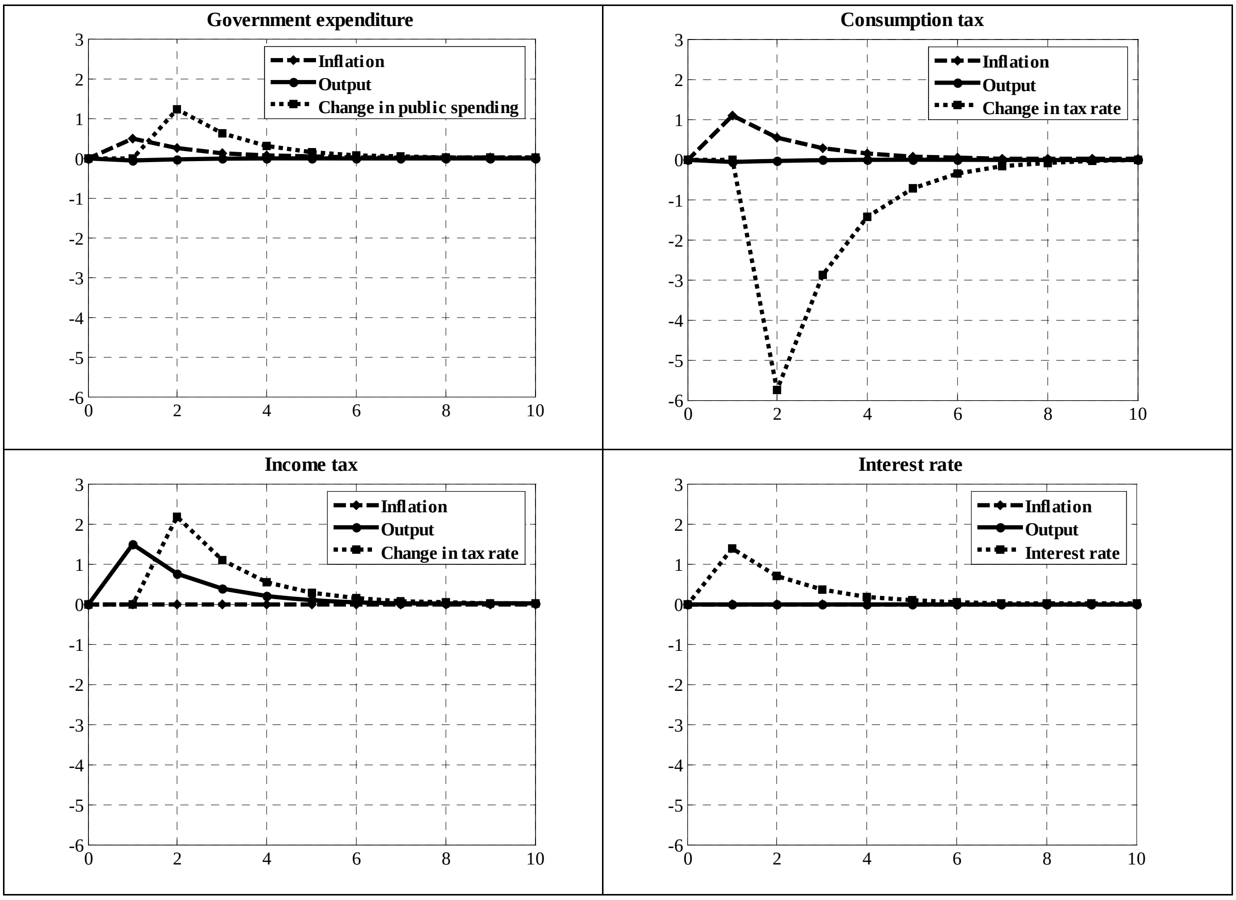

Figure 3: Optimal discretionary reaction to a unit demand shock with costless policy intervention

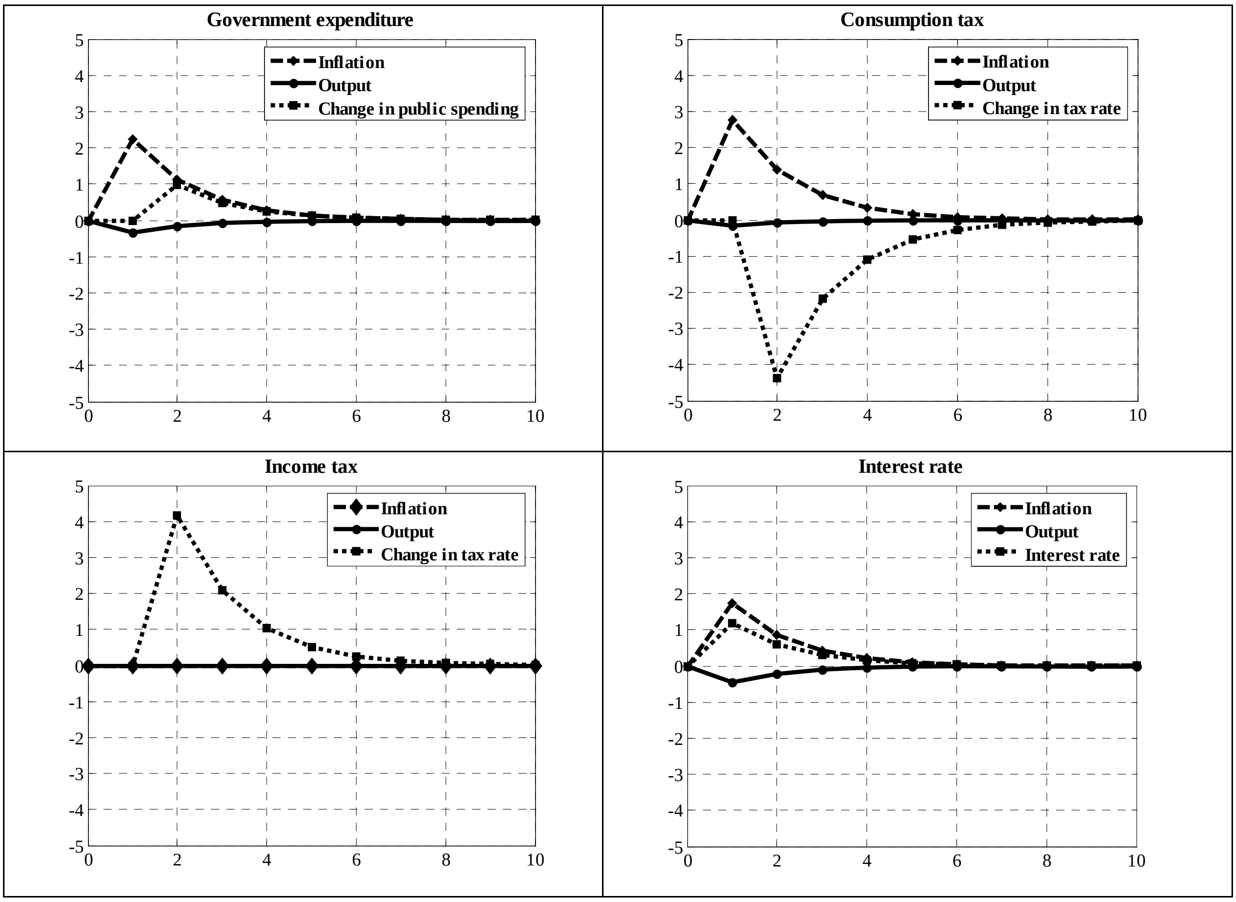

Figure 4: Optimal discretionary reaction to a unit cost-push shock with costless policy intervention

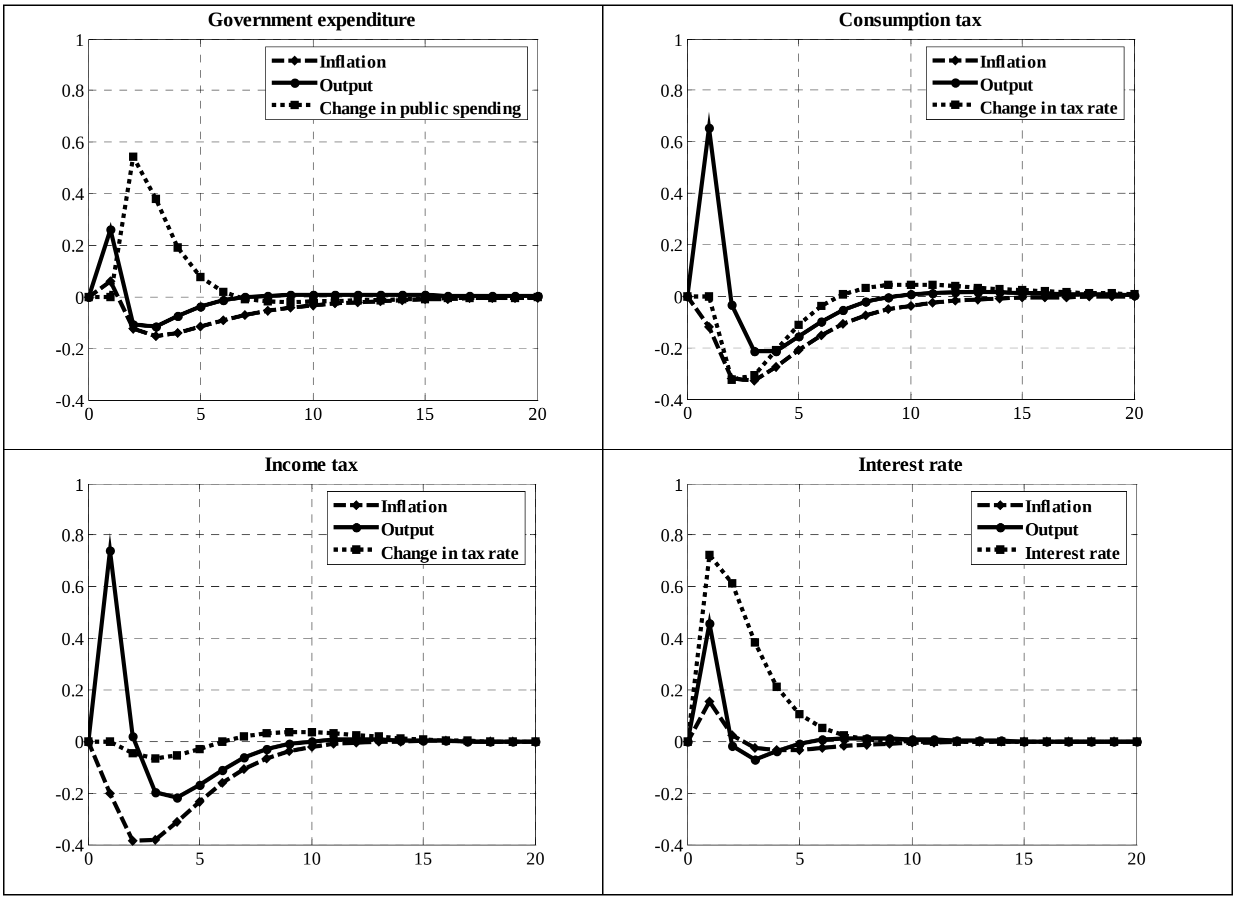

Figure 5: Optimal response to a unit demand shock under commitment

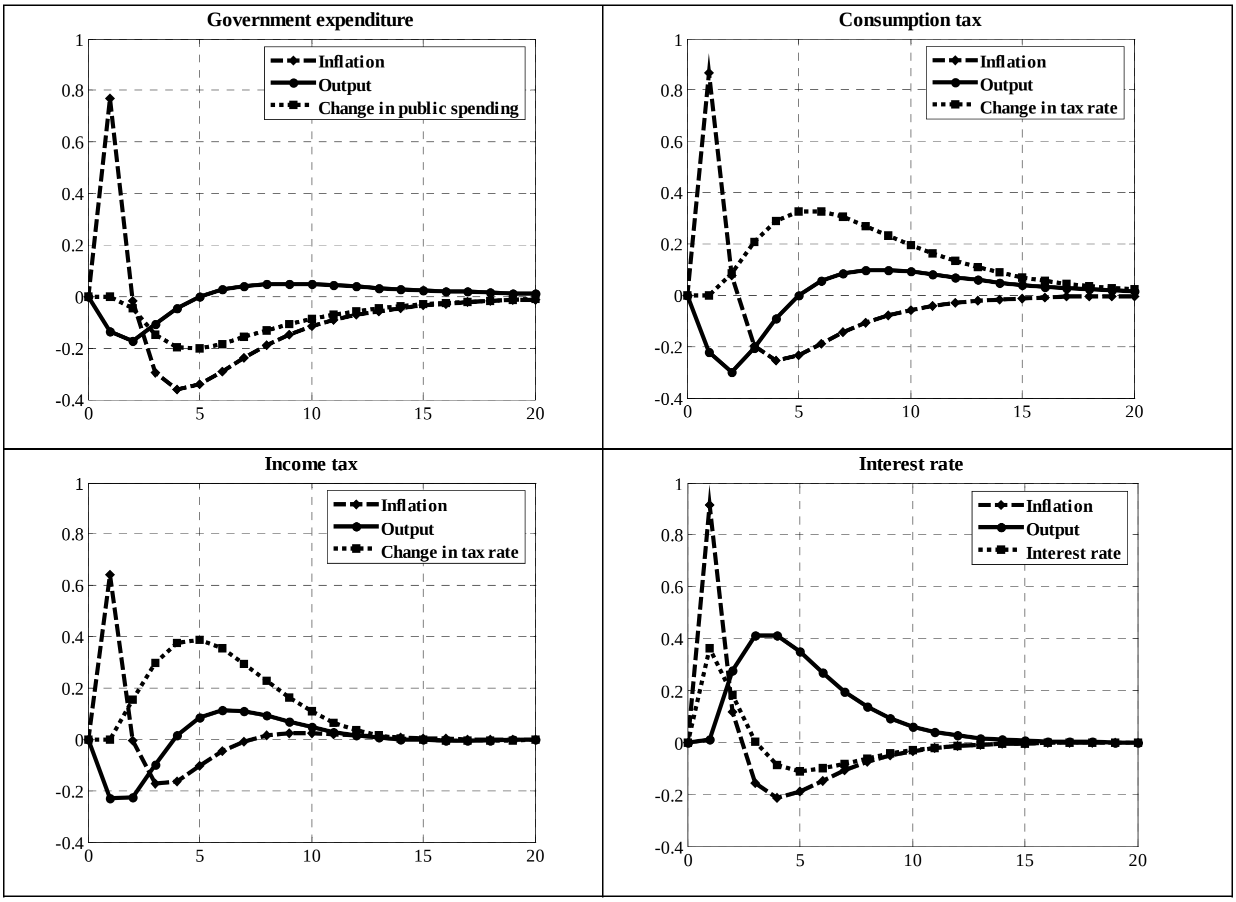

Figure 6: Optimal response to a unit cost-push shock under commitment

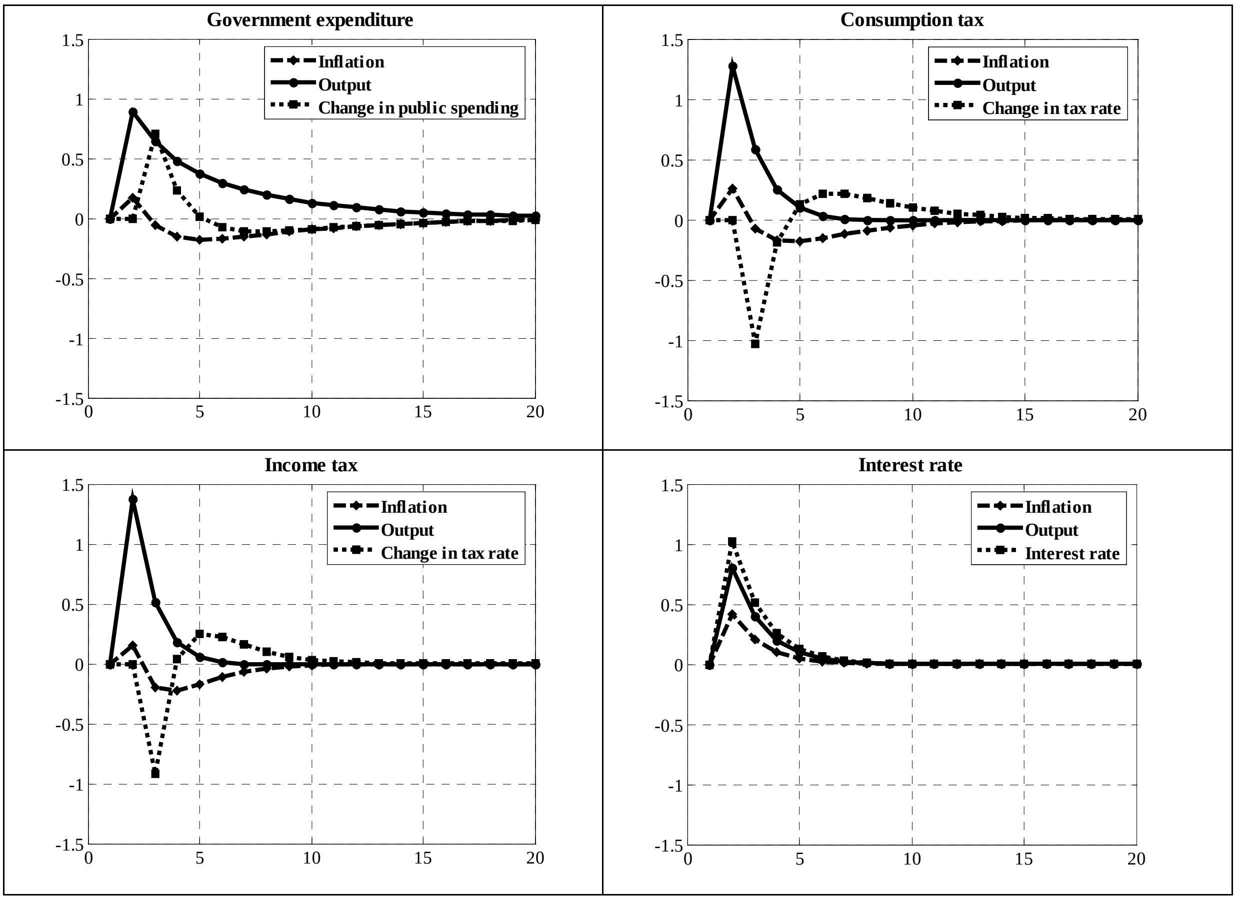

Figure 7: Simple rule performance under a unit demand shock

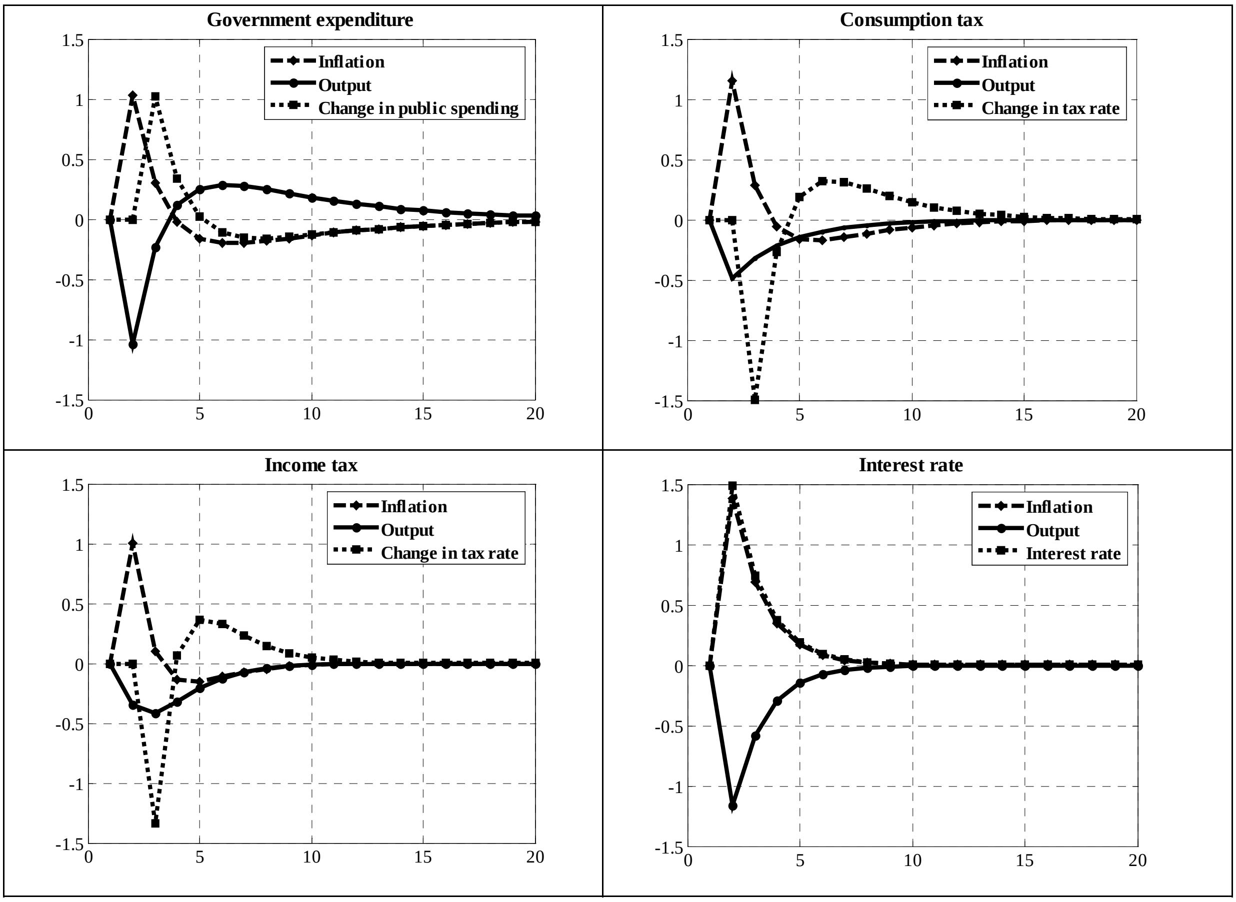

Figure 8: Simple rule performance under a unit cost-push shock

B. Derivation of Model Equations

Equations (8) and (9):

The representative household maximizes utility given in (1) and (2) under the budget constraint (7). For household consumption, the resulting first order conditions are

(A.1) $C_t^{-\sigma} = \lambda_t (1+\tau_t) P_t , \qquad C_{t+1}^{-\sigma} = \lambda_{t+1}(1+\tau_{t+1}) P_{t+1}$

The first-order condition for labor supply is

(A.2) $\vartheta N_t^{\phi} = \lambda_t (1-\iota_t) W_t$.

The optimality condition for saving in one-period bonds reads

(A.3) $\lambda_t = \beta (1+i_t) \lambda_{t+1}$.

Inserting (A.1) into (A.3), we obtain the Euler equation for the optimal inter-temporal allocation of consumption

(A.4) $$1 = \beta (1+i_t) E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{(1+\tau_t) P_t}{(1+\tau_{t+1}) P_{t+1}} \right].$$

With $\hat{x}_t = \ln X_t - \ln \overline{X}$ as the percentage deviation of variable X_t from its steady state $\overline{X}$ and $\beta = (1+\overline{r})^{-1}$, we obtain the log-linear approximation of (A.4) around the steady state, extended by the inclusion of the variable consumption tax

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma}(i_t + [\ln(1+\tau_t) - \ln(1+\overline{\tau})] - E_t[\ln(1+\tau_{t+1}) - \ln(1+\overline{\tau})] - E_t \hat{\pi}_{t+1} - \overline{r}) .$$

To simplify the expression, we adopt the approximation $\ln(1+\tau_t) - \ln(1+\overline{\tau}) \approx \frac{\tau_t - \overline{\tau}}{1+\overline{\tau}}$.

As $\frac{\tau_t - \overline{\tau}}{1+\overline{\tau}} = \frac{\overline{\tau}}{1+\overline{\tau}} \frac{\tau_t - \overline{\tau}}{\overline{\tau}}$ and $\frac{\overline{\tau}}{1+\overline{\tau}} \frac{\tau_t - \overline{\tau}}{\overline{\tau}} \approx \frac{\overline{\tau}}{1+\overline{\tau}} \hat{\tau}_t$, we obtain

(A.5) $$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma}\left(i_t + \frac{\overline{\tau}}{1+\overline{\tau}} [\hat{\tau}_t - E_t \hat{\tau}_{t+1}] - E_t \hat{\pi}_{t+1} - \overline{r} \right),$$

which is equation (8) in the text.

Equivalent first-order conditions apply to foreign households. The inter-temporal consumption path of foreign households is

$$\text{(A.6)} \quad 1 = \beta(1+i_t^*)E_t\left[\left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\sigma}\frac{(1+\tau_t^*)P_t^*}{(1+\tau_{t+1}^*)P_{t+1}^*}\right],$$

where we assume behavioral similarity between domestic and foreign households in the sense that $\beta = \beta^*$ and $\sigma = \sigma^*$. Asterisks denote foreign country variables. The monetary union has an integrated capital market, so that $i_t = i_t^*$. This allows equating (A.4) and (A.6) to

$$\text{(A.7)} \quad C_t = E_t\left[\left(\frac{1+\tau_{t+1}}{1+\tau_{t+1}^*}\frac{P_{t+1}}{P_{t+1}^*}\right)^{\frac{1}{\sigma}}\frac{C_{t+1}}{C_{t+1}^*}\right]\left(\frac{1+\tau_t^*}{1+\tau_t}\right)^{\frac{1}{\sigma}}\left(\frac{P_t^*}{P_t}\right)^{\frac{1}{\sigma}}C_t^*.$$

The expression $E_t\left[\left(\frac{1+\tau_{t+1}}{1+\tau_{t+1}^*}\frac{P_{t+1}}{P_{t+1}^*}\right)^{\frac{1}{\sigma}}\frac{C_{t+1}}{C_{t+1}^*}\right]$ is constant in the steady state and equal to one under symmetric initial conditions, i.e. with an equal initial endowment and steady-state consumption of domestic and foreign households. In log-linear notation, equation (A.7) reduces to

$$\text{(A.8)} \quad c_t = \frac{1}{\sigma}\left(p_t^* + \ln\left[1+\tau_t^*\right] - p_t - \ln\left[1+\tau_t\right]\right) + c_t^*.$$

The optimal labor supply of the representative household in a competitive labor market follows from (A.1) and (A.2) as

$$\frac{\vartheta N_t^{\phi}}{C_t^{-\sigma}} = \frac{(1-\iota_t)W_t}{(1+\tau_t)P_t}.$$

Together with $\ln(1+\tau_t) - \ln(1+\bar{\tau}) \approx \frac{\bar{\tau}}{1+\bar{\tau}}\hat{\tau}_t$ and $\ln(1-\iota_t) - \ln(1-\bar{\iota}) \approx -\frac{\bar{\iota}}{1-\bar{\iota}}\hat{\iota}_t$, we obtain

$$\text{(A.9)} \quad \hat{w}_t - \frac{\bar{\iota}}{1-\bar{\iota}}\hat{\iota}_t - \frac{\bar{\tau}}{1+\bar{\tau}}\hat{\tau}_t - \hat{p}_t = \phi\hat{n}_t + \sigma\hat{c}_t + \hat{\vartheta},$$

which is the labor supply equation (9) in the text.

Equation (15):

The log-linear approximation of real aggregate demand for domestic goods and services around the steady-state is

(A.10) $\hat{y}_t = c_Y(1-\alpha)\hat{c}_{H,t} + c_Y \alpha \hat{c}^*_{H,t} + g_Y \hat{g}_t$.

In a first step we replace $\hat{c}_{H,t}$ and $\hat{c}^*_{H,t}$ by the log-linear approximation of the demand equations (4) for domestic and foreign commodities

(A.11) $\hat{c}_{H,t} = -\eta(\hat{p}_{H,t} - \hat{p}_t) + \hat{c}_t$ and $\hat{c}^*_{H,t} = -\eta(\hat{p}_{H,t} - \hat{p}^*_t) + \hat{c}^*_t$.

The log-linear approximation of the price-level equation (5) around the steady-state is

(A.12) $\hat{p}_t = (1-\alpha)\hat{p}_{H,t} + \alpha \hat{p}_{F,t}$.

Because the share of domestic exports in foreign demand is very small, supply conditions in the small open economy do not affect foreign price levels. For the small open economy

(A.13) $p^*_t = p_{F,t}$

holds. Combining (A.10) to (A.13), we obtain

(A.14) $\hat{y}_t = c_Y(2-\alpha)\alpha\eta(\hat{p}_{F,t} - \hat{p}_{H,t}) + c_Y(1-\alpha)\hat{c}_t + c_Y \alpha \hat{c}^*_t + g_Y \hat{g}_t$.

Now we replace $\hat{p}_{F,t} - \hat{p}_{H,t}$ in (A.14) by the log-linear approximation of (A.8) and make use of $\hat{p}_t = (1-\alpha)\hat{p}_{H,t} + \alpha \hat{p}_{F,t}$. In a second step, we insert the log-linear approximation of the consumption equation (A.5) for domestic and foreign households and apply (A.14) for $t+1$. Under the assumptions $i_t = i^*_t$ and $\beta = \beta^*$, we obtain the inter-temporal output equation

$$\text{(A.15)}\quad \hat{y}_t = \left(\begin{array}{l} E_t\hat{y}_{t+1} - c_Y \dfrac{\omega_\alpha}{\sigma}\left(i_t - E_t\hat{\pi}_{H,t+1} - \bar{r}\right) - c_Y \dfrac{1-\alpha}{\sigma}\dfrac{\bar{\tau}}{1+\bar{\tau}}\left(\hat{\tau}_t - E_t\hat{\tau}_{t+1}\right) + g_Y\left(\hat{g}_t - E_t\hat{g}_{t+1}\right) \\ + c_Y \dfrac{1-\alpha-\omega_\alpha}{\sigma}\dfrac{\bar{\tau}^*}{1+\bar{\tau}^*}\left(\hat{\tau}^*_t - E_t\hat{\tau}^*_{t+1}\right) + c_Y\left(\omega_\alpha - 1\right)\left(E_t\hat{c}^*_{t+1} - \hat{c}^*_t\right) \end{array} \right),$$

with $\omega_\alpha = 1 + \alpha(2-\alpha)(\eta\sigma - 1)$, which is equation (15) in the text. Growth in foreign consumption, $E_t\hat{c}^*_{t+1} - \hat{c}^*_t$, can be replaced by the overall resource constraint of the foreign economy $E_t\hat{c}^*_{t+1} - \hat{c}^*_t = \frac{1}{c^*_Y} E_t \Delta y^*_{t+1} - \frac{g^*_Y}{c^*_Y} E_t \Delta g^*_{t+1}$.

For the closed economy, we have $\alpha = 0$ and $\omega_\alpha = 1$. Then equation (A.15) reduces to

$$\hat{y}_t = E_t\hat{y}_{t+1} - c_Y \frac{1}{\sigma}\left(i_t - E_t\hat{\pi}_{H,t+1} - \bar{r}\right) - c_Y \frac{1}{\sigma}\frac{\bar{\tau}}{1+\bar{\tau}}\left(\hat{\tau}_t - E_t\hat{\tau}_{t+1}\right) + g_Y\left(\hat{g}_t - E_t\hat{g}_{t+1}\right),$$

which is the familiar closed-economy IS equation augmented by government spending and a consumption tax.

Equation (16):

Monopolistically competitive firms produce output with constant returns to scale and with labor as the only factor of production. Each firm produces

$$Y_{h,t} = A_t N_{h,t}.$$

Its labor demand is

$$N_{h,t} = Y_{h,t} / A_t.$$

The demand for commodity h follows from

$$Y_{h,t} = C_{h,t} + C^*_{h,t} + G_{h,t}.$$

With the optimum conditions (6) and (10) and the aggregate demand equation (13), we obtain

$$Y_{h,t} = \left(\frac{P_{h,t}}{P_{H,t}}\right)^{-\varepsilon} Y_t.$$

Aggregate labor demand follows as

$$N_t = \int_0^1 N_{h,t}\,dh = \frac{Y_t}{A_t}\int_0^1 \left(\frac{P_{h,t}}{P_{H,t}}\right)^{-\varepsilon} dh.$$

The log-linear approximation of $\left(P_{h,t} / P_{H,t}\right)^{-\varepsilon}$ around the steady state

$$\ln\left(P_{h,t} / P_{H,t}\right)^{-\varepsilon} = -\varepsilon\left(p_{h,t} - p_{H,t}\right)$$

and the first-order approximation (see Galí/ Monacelli 2002, 2004)

$$-\varepsilon\int_0^1 \left(p_{h,t} - p_{H,t}\right) = 0$$

give the first-order approximation to the aggregate production function

(A.16) $\hat{y}_t = \hat{a}_t + \hat{n}_t$,

which is equation (16) in the text.

Equation (18):

The monopolistically competitive firms produce differentiated goods. Product differentiation implies that the firms have price-setting power. They maximize profits

$$\max D_{h,t} = P_{h,t}Y_{h,t} - W_t N_{h,t}$$

under the restriction

$$Y_{h,t} = C_{h,t} + C^*_{h,t} + G_{h,t}.$$

The private and public demand for h follows from the demand equations (6) and (10). The profit-maximizing price is

(A.17) $P^T_{h,t} = \dfrac{\varepsilon}{\varepsilon - 1}\dfrac{W_t}{A_t}$.

The optimal pricing rule (A.17) implies that monopolistically competitive firms charge a mark-up over nominal costs. With symmetry between domestic firms and a constant elasticity of substitution, the mark-up $\varepsilon/(\varepsilon - 1)$ is constant across firms and over time.

Under flexible prices the realized price equals the target price. Aggregating over the number of firms and dividing the mark-up rule by the domestic price level we get a log-linear steady-state relation between real marginal costs and the mark-up term

(A.18) $mc_t = -\mu$,

with $\mu = \ln(\varepsilon/[\varepsilon-1])$.

To consider the case of sticky prices, we adopt the Calvo model. Staggered price setting gives the New Keynesian Phillips curve (e.g. Galí/ Monacelli 2002, Woodford 2003) as

(A.19) $\hat{\pi}_{H,t} = \beta E_t \hat{\pi}_{H,t+1} + \kappa \hat{m}c_t$,

with $\kappa = \dfrac{(1-\theta)(1-\beta\theta)}{\theta}$ and with $1-\theta$ as the share of firms that reset prices in period t.

Real marginal costs (A.18) are constant under constant returns to scale. In logarithmic terms they equal

$mc_t = w_t - p_{H,t} - a_t$.

Combining this expression with labor demand (A.16) and the wage equation (A.9) gives the log-linear approximation of marginal costs around the steady state

(A.20) $m\hat{c}_t = \phi\hat{y}_t + \sigma\hat{c}_t + \ln\hat{n}\,\vartheta + \dfrac{\bar{\iota}}{1-\bar{\iota}}\hat{\iota}_t + \dfrac{\bar{\tau}}{1+\bar{\tau}}\hat{\tau}_t - (\hat{p}_{H,t} - \hat{p}_t) - (1+\phi)\hat{a}_t$.

We now combine (A.20) with (A.8) and (A.14) and obtain equation (18) in the text

$$\text{(A.21)}\quad \hat{m}c_t = \left(\begin{array}{l} \left(\phi + \dfrac{\sigma}{c_Y\omega_\alpha}\right)\hat{y}_t - \dfrac{g_Y\sigma}{c_Y\omega_\alpha}\hat{g}_t + \dfrac{1-\alpha}{\omega_\alpha}\dfrac{\bar{\tau}}{1+\bar{\tau}}\hat{\tau}_t + \dfrac{\bar{\iota}}{1-\bar{\iota}}\hat{\iota}_t + \ln\hat{n}\,\vartheta \\ -(1+\phi)\hat{a}_t + \left(1-\dfrac{1-\alpha}{\omega_\alpha}\right)\dfrac{\bar{\tau}^*}{1+\bar{\tau}^*}\hat{\tau}_t^* + \sigma\left(1-\dfrac{1}{\omega_\alpha}\right)\left(\dfrac{\hat{y}_t^*}{c_Y^*} - \dfrac{g_Y^*\hat{g}_t^*}{c_Y^*}\right) \end{array} \right),$$

with $\omega_\alpha = 1 + \alpha(2-\alpha)(\eta\sigma - 1)$.

Equation (21):

Equation (A.21) allows deriving the equilibrium or natural level of output in the absence of nominal rigidities, i.e. the flexible-price level y_t^f . In the flexible-price case firms adjust prices in every period and charge a constant mark-up according to the pricing rule (A.18). We can thus write

$$mc_t = -\mu = \begin{pmatrix} \left(\phi + \dfrac{\sigma}{c_Y \omega_\alpha}\right) y_t^f - \dfrac{g_Y \sigma}{c_Y \omega_\alpha} g_t + \dfrac{1-\alpha}{\omega_\alpha} \dfrac{\bar{\tau}}{1+\bar{\tau}} \tau_t + \dfrac{\bar{\iota}}{1-\bar{\iota}} \iota_t + \ln \vartheta \\ -(1+\phi) a_t + \left(1 - \dfrac{1-\alpha}{\omega_\alpha}\right) \dfrac{\bar{\tau}^*}{1+\bar{\tau}^*} \tau_t^* + \sigma \left(1 - \dfrac{1}{\omega_\alpha}\right) \left(\dfrac{y_t^*}{c_Y^*} - \dfrac{g_Y^* g_t^*}{c_Y^*} \right) \end{pmatrix}$$

and obtain

$$\text{(A.22)} \quad y_t^f = \begin{pmatrix} -\dfrac{\omega_\alpha}{\sigma + \phi \omega_\alpha} \mu + \dfrac{g_Y \omega_\alpha}{c_Y \phi \omega_\alpha + \sigma} g_t - \dfrac{1-\alpha}{c_Y \phi \omega_\alpha + \sigma} \dfrac{\bar{\tau}}{1+\bar{\tau}} \tau_t \\ -\dfrac{c_Y \phi \omega_\alpha + \sigma}{c_Y \omega_\alpha} \dfrac{\bar{\iota}}{1-\bar{\iota}} \iota_t - \dfrac{\omega_a}{\phi \omega_\alpha + \sigma} \ln \vartheta + \dfrac{(1+\phi)\omega_\alpha}{\phi \omega_\alpha + \sigma} a_t \\ + \dfrac{c_Y (1-\alpha-\omega_\alpha)}{c_Y \phi \omega_\alpha + \sigma} \dfrac{\bar{\tau}^*}{1+\bar{\tau}^*} \tau_t^* + \dfrac{c_Y \sigma (1-\omega_\alpha)}{c_Y \phi \omega_\alpha + \sigma} \left(\dfrac{y_t^*}{c_Y^*} - \dfrac{g_Y^* g_t^*}{c_Y^*} \right) \end{pmatrix}.$$

The latter shows that the flexible-price level of output depends negatively on the mark-up and that it is conditional on foreign output. The flexible-price equilibrium output thus fluctuates conditional on the above determinants.

Variable $\bar{r}_t$ is the equilibrium real interest rate conditional on foreign demand, technology and changes in preferences. We insert the equilibrium values for $\hat{y}_t^f$ and $E_t \hat{y}_{t+1}^f$ from (A.21) or (A.22) in (A.15) and solve the latter for the flexible-price real interest rate. We obtain

$$\bar{r}_t = \begin{pmatrix} \bar{r} + \sigma \dfrac{1+\phi}{c_Y \omega_\alpha \phi + \sigma} E_t \Delta a_{t+1} - \dfrac{\sigma}{c_Y \omega_\alpha \phi + \sigma} E_t \Delta \ln \vartheta_{t+1} \\ -c_Y \phi \sigma \dfrac{1-\omega_\alpha}{c_Y \omega_\alpha \phi + \sigma} E_t \Delta c_{t+1}^* - c_Y \phi \dfrac{1-\alpha-\omega_\alpha}{c_Y \omega_\alpha \phi + \sigma} \dfrac{\bar{\tau}^*}{1+\bar{\tau}^*} E_t \Delta \hat{\tau}_{t+1}^* \end{pmatrix},$$

where $E_t \Delta c_{t+1}^*$ can be replaced by $E_t \Delta c_{t+1}^* = \dfrac{1}{c_Y^*} E_t \Delta y_{t+1}^* - \dfrac{g_Y^*}{c_Y^*} E_t \Delta g_{t+1}^*$.