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Fiscal rules and monetary policy in a dynamic stochastic general equilibrium model

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Abstract

In this paper an anti-cyclical fiscal policy rule is introduced into a dynamic stochastic general equilibrium model with New-Keynesian features. The rule allows the deficit to deviate from target in proportion to the impact of automatic stabilisers while any additional impact on the deficit, for example on interest expenditure, has to be offset through adjustments of government consumption or taxes. The size of the automatic stabilisers is endogenously determined as the change in the primary deficit that is induced by economic fluctuations for a given tax system. The model is calibrated, and it is shown how the conditions for monetary policy to secure stability and determinacy of the model's equilibrium depend on the fiscal policy rule and, in particular, on the means used to fulfil the rule. It is demonstrated that the Taylor principle holds for reasonable values of the fiscal policy parameter if fiscal policy relies on changes in lump-sum taxes. This runs counter to the benchmark result of Leeper (1991). The same goes for the cases that consumption taxes, profit taxes or government consumption are adjusted to fulfil the fiscal rule. However, if the fiscal rule is met through adjustments of wage or interest tax rates, the range of values of the monetary policy parameter that ensures stability and determinacy change significantly.

Keywords: dynamic stochastic general equilibrium model, monetary policy rules, fiscal policy rules, stability

JEL classification: E31, E32, E52, E62, E63

Non-Technical Summary

This paper discusses how monetary policy is affected when fiscal policy follows an anti-cyclical fiscal rule. The analytical framework is a New-Keynesian dynamic stochastic general equilibrium model in which monetary policy follows a Taylor-type rule. The key question is how the conditions for monetary policy to ensure equilibrium stability and determinacy are influenced by the incorporation of the fiscal rule. In this context we also discuss how the results depend on the choice of the fiscal policy decision variable (lump-sum or distortionary taxes, government consumption).

The fiscal policy rule considered in this paper requires that deviations of the deficit ratio from a given medium-term target must be proportional to the impact of the automatic stabilisers. Any additional change in the deficit has to be offset by an adjustment of fiscal policy. The deficit target in the model is the cyclically adjusted deficit ratio and the rule implies that the deficit ratio is allowed to deviate from the target in an anti-cyclical manner. In particular, the rule would be in line with the Maastricht Treaty and the Stability and Growth Pact if the rule's proportionality factor is set appropriately with regard to the scale of the business cycle fluctuations and the medium-term deficit target.

In order to model the working of the automatic stabilisers several types of distortionary taxes are introduced. More specifically, taxation distorts investment, labour supply, and consumption decisions. The distortions can vary over time. Therefore, Ricardian equivalence does not hold and the timing of taxation matters. In particular, tax smoothing and thus an anti-cyclical fiscal policy may enhance welfare. This is one important argument for the application of a fiscal rule in the spirit of the Stability and Growth Pact as compared to a rule that adjusts the deficit ratio independently of the economic environment.

The different tax rates incorporated in the model or government consumption can be used to fulfil the fiscal policy rule. Furthermore, adjustments of tax rates can be interpreted as changes in transfers or subsidies. The question of how the rule is fulfiled forms an integral part of fiscal policy design and should thus be considered when discussing the properties of fiscal policy rules. Indeed, it is shown that the choice of the fiscal policy instrument is relevant for the stability and determinacy results.

As formulated, the fiscal rule does not by itself yield explosive debt growth for reasonable values of the model parameters. In particular, when lump-sum taxes are adjusted to fulfil the rule the stability properties of the model are not affected by fiscal policy and the Taylor principle still holds, ie the model's equilibrium is stable and determinate if the interest rate reaction of monetary policy to changes in inflation is strong enough. However, changes in tax rates or government consumption influence agents' decisions. Therefore, if these policy variables are adjusted to fulfil the rule, there is an indirect channel through which the stability and determinacy of the model's equilibrium can potentially be impaired.

As model simulations show, if consumption taxes, profit taxes or government consumption are employed as policy instruments, the Taylor principle is still valid. However, if the fiscal rule is met through adjustments of wage or interest tax rates, the range for the monetary policy parameter that ensures stability and determinacy is significantly affected. The reason for this is that the endogenous changes in wage or interest tax rates have an impact on the after-tax return on labour and capital. The implied adjustment of labour and capital inputs influences the real return on capital and, thus, ultimately the real interest rate. Therefore, the transmission of monetary policy changes.

If labour tax rates are used as the fiscal policy instrument, the Taylor principle might even be reversed, ie active monetary policy can induce indeterminacy and passive monetary policy determinacy of the model's equilibrium. When interest tax rates are adjusted to fulfil the rule, similar effects are present. In that case, however, another factor dominates: the fiscal policy maker partly offsets an increase in the nominal interest rate by monetary policy through an endogenous increase in the interest tax rate. Therefore, monetary policy possibly does not succeed in its attempt to increase the real after-tax interest rate and the equilibrium is indeterminate for a broad range of the policy parameters.

Nichttechnische Zusammenfassung

In diesem Papier wird untersucht, wie die Wirkungsweise der Geldpolitik beeinflusst wird, wenn die Fiskalpolitik einer anti-zyklischen Regel folgt. Als analytischer Rahmen dient ein Neu-Keynesianisches dynamisches stochastisches allgemeines Gleichgewichtsmodell, in dem die Geldpolitik durch eine Taylor-Regel beschrieben wird. Der Fokus liegt auf der Frage, inwiefern die Bedingungen, unter denen die geldpolitische Regel zu einem stabilen und determinierten Modellgleichgewicht führt, durch die Berücksichtigung der Fiskalpolitik beeinflusst werden. Dabei wird auch diskutiert, wie die Ergebnisse von der Wahl verschiedener fiskalpolitischer Entscheidungsvariablen (verzerrende und unverzerrende Steuern, staatlicher Konsum) abhängen.

Die fiskalpolitische Regel gibt vor, dass Abweichungen der Defizitquote von einer mittelfristigen Zielgröße proportional zu den automatischen Stabilisatoren sein müssen. Zusätzliche Abweichung sind durch Anpassungen in der Fiskalpolitik auszugleichen. Das Defizitziel im Modell entspricht der zyklisch bereinigten Defizitquote und die Regel impliziert, dass die Abweichung der Defizitquote von der Zielgröße anti-zyklisch ist. Insbesondere steht die Regel mit dem Maastricht-Vertrag und dem Stabilitäts- und Wachstumspakt in Einklang, wenn der Proportionalitätsfaktor dem Ausmaß der Konjunkturschwankungen und der Höhe des Defizitziels angemessen gewählt wird.

Um die automatischen Stabilisatoren in dem Modell abzubilden, werden verschiedene Arten von verzerrenden Steuern berücksichtigt. Genauer werden Investitions-, Arbeitsangebots- und Konsumentscheidung durch die Steuern verzerrt. Die Verzerrungen können im Zeitverlauf variieren. Daher gilt die Ricardianische Äquivalenz nicht und der Zeitpunkt der Besteuerung ist von Bedeutung. Insbesondere kann die Wohlfahrt erhöht werden, wenn die Steuerzahlungen geglättet werden, dass heißt wenn die Fiskalpolitik anti-zyklisch ist. Dies ist ein wichtiges Argument für eine fiskalpolitische Regel im Sinne des Stabilitäts- und Wachstumspakts in Vergleich zu einer Regel, bei der die Defizitquote unabhängig vom ökonomischen Umfeld angepasst wird.

Um die fiskalpolitische Regel zu erfüllen, können die verschiedenen Steuersätze oder der Staatskonsum angepasst werden. Anpassungen bei den Steuersätzen können dabei auch als Veränderung von Transfers oder Subventionen interpretiert werden. Die Frage, wie die Regel eingehalten wird, bildet einen wichtigen Bestandteil der Formulierung einer Fiskalpolitik und sollte daher berücksichtigt werden, wenn über die Eigenschaften finanzpolitischer Regeln diskutiert wird. Tatsächlich ist die Wahl des fiskalpolitischen Instruments auch für die hier vorgestellten Ergebnisse bezüglich Stabilität und Determiniertheit des Modellgleichgewichts von Bedeutung.

Die Regel ist so formuliert, das sie für sich genommen (bei einer plausiblen Wahl der Modellparameter) nicht zu einem explosiven Wachstum des Schuldenstands führt. Insbesondere bleiben die Stabilitätseigenschaften des Modells erhalten, wenn die Regel mit Hilfe von Pauschalsteuern erfüllt wird. In diesem Fall gilt das Taylor-Prinzip, dass heißt das Modellgleichgewicht ist stabil und determiniert, wenn die Zinsreaktion der Geldpolitik auf Inflationsänderungen hinreichend stark ausfällt. Veränderungen der Steuersätze oder des Staatskonsums beeinflussen allerdings die Entscheidungen der Wirtschaftssubjekte. Falls die Regel über Veränderungen dieser Politikvariablen eingehalten wird, können Stabilität und Determiniertheit des Modellgleichgewichts daher durch diesen indirekten Zusammenhang beeinträchtigt werden.

Modellsimulationen zeigen, dass bei der Wahl von Konsumsteuern, Gewinnsteuern oder Staatskonsum als Politikinstrument das Taylor-Prinzip weiterhin gilt. Wenn die fiskalpolitische Regel allerdings durch eine Anpassung von Lohn- oder Zinsbesteuerung erfüllt wird, verändert sich der Parameterbereich deutlich, in dem die Geldpolitik Stabilität und Determiniertheit sicherstellt. Der Grund hierfür ist, dass sich endogene Veränderungen der Lohn- und Zinssteuersätze im Nettolohn- und Nettozinseinkommen niederschlagen. Die daraus resultierende Anpassung des Arbeits- und Kapitaleinsatzes beeinflusst den realen Ertrag des Kapitals und damit letztlich den realen Zinssatz. Daher verändert sich die Transmission der Geldpolitik.

Wenn der Lohnsteuersatz als fiskalpolitisches Instrument verwendet wird, kann sich das Taylor-Prinzip sogar umkehren, dass heißt eine aktive Geldpolitik kann zu Indeterminiertheit und eine passive Geldpolitik zu Determiniertheit des Modellgleichgewichts führen. Falls die Steuersätze auf Zinseinkommen verwendet werden, um die fiskalpolitische Regel zu erfüllen, ergibt sich ein ähnlicher Effekt. Allerdings wird dieser durch einen anderen Faktor überlagert: Die Fiskalpolitik gleicht eine Erhöhung des nominalen Zinssatz durch die Geldpolitik teilweise aus, indem sie den Steuersatz auf Zinsen endogen erhöht. Daher ist die Geldpolitik mit ihrem Versuch, den realen Zinssatz nach Steuern zu erhöhen, eventuell nicht erfolgreich und das Gleichgewicht ist für einen großen Bereich der Politikparameter indeterminiert.

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1 Introduction

In this paper conditions for monetary and fiscal policy rules to ensure equilibrium stability and determinacy are discussed in a dynamic stochastic general equilibrium (DSGE) model with New-Keynesian features and capital accumulation. Several recent papers study fiscal policy alongside monetary policy in DSGE models and, in particular, focus on how the stability properties of monetary policy rules are influenced by fiscal policy. A starting point of this literature is provided by Leeper (1991) who found that an active monetary and a passive fiscal policy or *vice versa* are needed for stability and determinacy of the model's equilibrium. However, this result depends on the model and on the specific formulation of the policy rules. For example, Lubik (2003) (in a DSGE model with capital accumulation and lump-sum taxation), Leith and von Thadden (2004) (in a Blanchard-Yaari overlapping generations framework with lump-sum taxation) or Railavo (2004) (in a DSGE model without capital accumulation and with distortionary income taxes) discussed how the stability properties of the Taylor rule depend on the combination of active and passive behaviour of the monetary and fiscal authorities in the recent past. Schmitt-Grohé and Uribe (2004) go a step further and show that it is of little consequence for welfare whether fiscal policy is active or passive in a model with capital accumulation and distortionary taxation. All these authors follow Leeper (1991) in assuming a fiscal policy rule that adjusts (lump-sum or income) taxes to correct a deviation of government liabilities or the deficit from their target paths in proportion to the deviation.

The fiscal policy rule considered in this paper differs from this common specification in two respects. First, the rule requires that deviations of the deficit ratio from a given medium-term target must be proportional to the impact of the automatic stabilisers. Any additional impact on the deficit, for example on interest

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expenditure, has to be offset. The size of the automatic stabilisers is endogenously determined as the change in the primary deficit that is induced by economic fluctuations for a given tax system. Second, the model incorporates lump-sum, wage, interest, profit and consumption taxes as well as government consumption, and we considered how the use of different fiscal policy instruments influences the stability and determinacy results. The means by which a rule is fulfiled form an integral part of fiscal policy design and should thus be taken into account when the properties of fiscal rules are discussed.

As specified, the fiscal rule can be used to study systematic anti-cyclical fiscal policy if it is incorporated into a business cycle framework. The deficit target of the model is the cyclically adjusted deficit ratio, and the rule implies that the deficit ratio is allowed to deviate from the target in an anti-cyclical manner. In particular, the rule would be in line with the Maastricht Treaty and the Stability and Growth Pact if the rule's proportionality factor is set appropriately with regard to the size of the business cycle fluctuations and the medium-term deficit target.

The DSGE model employed in this paper is similar to those in the above-mentioned literature. Monetary policy is described by a Taylor-type rule (Taylor (1993)). Goods markets are monopolistic competitive and there are costs of price adjustments to establish a link between nominal and real variables. The model contains capital as a production factor. With the introduction of capital the real interest rate is determined by a no-arbitrage condition and other variables have to adjust endogenously to induce capital market equilibrium. This is crucial eg for the result of Dupor (2001) who shows how the transmission of monetary policy and thus also the stability properties of monetary policy rules are influenced by equilibrium considerations. The model also takes account of adjustment costs of capital accumulation. This enhances the performance of the model in the sense that it reduces the unrealistically strong reactions of investment that occur in models without adjustment costs. Another important implication for the context considered here is that it may also change the regions of the parameter space that ensures stability and determinacy of the model's equilibrium, see eg Lubik (2003).

To model the working of the automatic stabilisers distortionary taxes (as eg in Schmitt-Grohé and Uribe (2004)) are introduced. As is common in the literature with a stronger focus on fiscal policy questions, different types of income taxes are distinguished and indirect taxation is also depicted. Thus, taxation distorts investment, labour supply, and consumption decisions. The distortions can vary (independently of each other) over time. Therefore, Ricardian equivalence does not hold and the timing of taxation matters. In particular, tax smoothing and therefore an anti-cyclical fiscal policy may enhance welfare (see Greenwood and Huffman (1991) for an early discussion of how tax policy can be used to stabilise cyclical fluctuations in a real business cycle model). This is one important argument for the application of a fiscal rule in the spirit of the Stability and Growth Pact as compared to a rule that holds the deficit ratio fixed or adjusts it independently of the economic environment.

For reasonable values of the fiscal policy parameter the rule that is discussed here does not lead per se to explosive debt growth. Thus, the notion of Leeper (1991) of active versus passive fiscal policy cannot be applied. In particular, when lump-sum taxes are adjusted to fulfil the rule, the model dynamics change only if fiscal policy is strongly pro-cyclical. This runs counter to the benchmark result of Leeper (1991). However, changes in tax rates or government consumption influence agents' decisions, so that the implementation of the rule can change the other eigenvalues of the model. Therefore, there is an indirect channel through which the stability and determinacy of the model's equilibrium might be impaired. In this sense the analysis provided here is similar to that of Leith and von Thadden (2004). They also show how the model dynamics are influenced indirectly if Ricardian equivalence does not hold, even if the equation for debt dynamics introduces no source of instability in itself.

The model has too many equations to be solved analytically. Therefore, it is calibrated with regard to German time series moments. Simulations of the calibrated model show that the stability properties depend on whether government consumption or tax rates are adjusted to fulfil the fiscal rule. As with lump-sum taxation, the Taylor principle is valid (ie the model's equilibrium is stable and determinate if the interest rate reaction of monetary policy to changes in inflation is strong enough) if consumption taxes, profit taxes or government consumption are adjusted to fulfil the fiscal rule and fiscal policy is not too strongly pro-cyclical. However, if the fiscal rule is met through adjustments of wage or interest tax rates, the range for the monetary policy parameter that ensures stability and determinacy is significantly affected. The reason for this is that the changes in wage and interest tax rates have an impact on the return on labour and capital. The implied adjustment of labour and capital inputs influences the real return on capital and, thus, ultimately the real interest rate. Therefore, the transmission of monetary policy can change.

In the case that labour tax rates are used as the fiscal policy instrument the Taylor principle might even be reversed, ie active monetary policy might induce indeterminacy and passive monetary policy determinacy of the model's equilibrium. When interest tax rates are used, similar effects are present. In this case, however, another factor predominates: the fiscal policy maker partly offsets an increase in the nominal interest rate by monetary policy through an endogenous increase in the interest tax rate. Therefore, the monetary policy maker possibly does not succeed in his attempt to increase the real after-tax interest rate and the equilibrium is indeterminate for a broad range of the policy parameters.

The results also depend on whether capital adjustment costs are considered. In this respect they are similar to those of Lubik (2003). The reason for this is that adjustment costs strongly influences the investment reactions and, thus, significantly change the dynamics of the real interest rate. Overall, the analysis underlines the importance of endogenous capital and labour adjustments due to changing returns for the transmission of monetary policy.

The next section describes the model and contains the details of the calibration. The main results concerning stability and determinacy of the model's equilibrium are derived in Section 3. Section 4 concludes.

2 The model

The model considered here describes a standard New-Keynesian economy. To improve the model's capability to capture adjustment dynamics capital accumulation and adjustment costs of capital accumulation are introduced. As in the typical New-Keynesian model, firms face adjustment costs in price-setting and good markets are monopolistic competitive. Thus, fluctuations in nominal variables trigger real effects. Monetary policy determines nominal interest rates on short-term bonds according to a Taylor-type rule, while real interest rates are determined through equilibrium conditions. Government consumption might be financed by lump-sum taxes, proportional income and consumption taxes, seigniorage or debt. Since it is assumed that households have an infinite planning horizon, they will be indifferent with respect to the timing of lump-sum taxes to finance a specific amount of debt, ie the model displays Ricardian equivalence in this respect. However, taxation of income and consumption distort labour supply, consumption, investment, and pricing decisions. By varying the tax rates over time the fiscal policy maker can, therefore, influence the intertemporal decisions of agents, ie Ricardian equivalence no longer holds. Given the exogenous paths for all but one of the fiscal decision variables, the model is closed by a deficit rule that is specified as a function of the automatic stabilisers. A summary of the model equations is given in Appendix A.

2.1 Households

The representative household consumes a basket of differentiated goods:

$$C_t = \left(\int_0^1 C_{jt}^{(\varepsilon-1)/\varepsilon} \mathrm{d}j \right)^{\varepsilon/(\varepsilon-1)} , \quad \varepsilon > 1 .$$

Minimisation of expenditure leads to the following demand function

$$C_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\varepsilon} C_t ,$$

where P_{jt} is the price of C_{jt}, P_t the price of the consumption basket C_t, and ε is the elasticity of demand with respect to good C_{jt}. The household holds three types of assets: money M_t, government bonds B_t, and physical capital K_t. Government bonds pay a gross nominal return R_t and are denoted in the price of the consumption basket. The gross rental rate for capital is termed R_t^s. The household sector owns the firms, and firms' profits $\mathcal{P}_t$ (net of taxes) are distributed to households in a lump-sum fashion. The household supplies labour N_t, receives a nominal wage payment W_t per efficiency unit of labour A_t (ie nominal wage income of the household is $W_t A_t N_t$), and pays taxes T_t^h. To explain money holdings, a standard money-in-the-utility approach is adopted. The instantaneous utility function takes the form:

$$U(C_t, N_t, M_t/P_t) = \log(C_t) - \theta N_t + \chi \log(M_t/P_t) , \quad \chi, \theta > 0 .$$

Capital depreciates at a rate $\delta \in [0, 1]$ and labour productivity A_t grows at the rate $A_t/A_{t-1} = a \geq 1$. Adjustment costs of capital accumulation are described by a twice differentiable, strictly concave function Ψ that increases if the investment ratio I_t/K_{t-1} increases and that fulfils

$$\Psi(a + \delta - 1) = a + \delta - 1 \;\text{ and }\; \Psi'(a + \delta - 1) = 1 .$$

As will become clear later on, this implies that in the deterministic steady state of the model I_t/K_{t-1} is equal to $a + \delta - 1$ and adjustment costs are zero (see Baxter and Crucini (1993) for this formulation of adjustment costs). Given depreciation and adjustment costs, investment I_t adds to the capital stock according to

$$K_t - (1-\delta)K_{t-1} = \Psi(I_t/K_{t-1})K_{t-1} \ .$$

It is assumed that there are lump-sum as well as activity-dependent taxes. The real value of lump-sum taxes is denoted as T_t^l. Activity-dependent are the taxes on labour income $W_t A_t N_t / P_t$, the taxes on interest paid on bond holdings $(R_{t-1} - 1)B_{t-1}/P_t$, the taxes on the return on capital $(R_t^s - 1 - \delta)K_{t-1}$ and the taxes on consumption C_t. Labour, interest and consumption tax rates are termed τ_t^w, τ_t^r, $\tau_t^c \in [0,1)$, respectively. The tax rates may vary over time, implying a distortion of intertemporal decisions. Capital depreciation can be deducted. To sum up, taxes are given as

$$T_t^h = T_t^l + \tau_t^w \frac{W_t A_t}{P_t} N_t + \tau_t^r \left((R_{t-1} - 1)\frac{B_{t-1}}{P_t} + (R_t^s - 1 - \delta)K_{t-1} \right) + \tau_t^c C_t \ .$$

Given these assumptions, the household's problem might be stated as follows:

$$\begin{aligned}
\max \ & E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t, M_t/P_t) \\
s.\ t. \ & \frac{W_t A_t}{P_t} N_t + (R_t^s - 1)K_{t-1} + \mathcal{P}_t + R_{t-1}\frac{B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} \\
& \geq I_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} + C_t + T_t^h \ , \\
& \left(\Psi(I_t/K_{t-1}) + 1 - \delta\right) K_{t-1} \geq K_t \ , \quad K_{-1} \ , \ B_{-1} \ , \ M_{-1} \ \text{given.}
\end{aligned}$$

In the following $\pi_t = P_t/P_{t-1}$ denotes the inflation rate. Furthermore, let f_t be the value of a function f where all arguments are variables with time index t and let f_j denote the derivative of a function f with respect to the j-th argument.

The Lagrange multiplier Λ_t of the household's budget constraint, ie the shadow price of assets, equals the marginal utility of consumption adjusted for the costs caused by taxes:

$$\Lambda_t = \frac{U_{1t}}{1 + \tau_t^c} \ .$$

The Lagrange multiplier of investment is denoted as $\Lambda_t q_t$. The other necessary conditions of the household's problem are

$$
\begin{aligned}
& -U_{2t} = \Lambda_t(1-\tau_t^w)W_tA_t/P_t \ , \\
& \Psi'\left(\frac{I_t}{K_{t-1}}\right)^{-1} = q_t \ , \\
& \beta E_t \frac{1+(1-\tau_{t+1}^r)(R_t-1)}{\pi_{t+1}}\Lambda_{t+1} = \Lambda_t \ , \\
& \beta E_t \frac{1}{\pi_{t+1}}\Lambda_{t+1} = \Lambda_t - U_{3t} \ , \\
& \beta E_t \Lambda_{t+1}\Bigg((1-\tau_{t+1}^r)(R_t^s-1)+\tau_{t+1}^r\delta \\
& \qquad + q_{t+1}\left(1-\delta+\Psi\left(\frac{I_{t+1}}{K_t}\right)\right)-\frac{I_{t+1}}{K_t}\Bigg) = q_t\Lambda_t \ .
\end{aligned} \tag{1}
$$

The first equation describes the household's labour supply decision. It equates the marginal utility of leisure to the marginal return of an additional unit of labour supply priced at Λ_t. The latter is the increase in utility if the additional income is spent on consumption. The left-hand side rises with θ, ie with the weight of leisure in the instantaneous utility function of the household. The right-hand side falls when τ_t^w or τ_t^c rise. Thus, a higher value of the weight of leisure or higher tax rates on labour income or consumption require *ceteris paribus* that consumption falls.

The second equation defines the shadow price of investment (Tobin's q), ie the number of units of output which must be foregone to increase the capital stock by one unit. Because of the assumptions about Ψ it is one in the steady state (no adjustment costs) and higher (lower) than one for an investment capital ratio above (below) the steady-state value.

The third equation is the Euler equation for the intertemporal substitution of consumption that is familiar from a small New-Keynesian model with government bonds as the sole asset. It states that in the optimum the marginal utility of consumption today is the same as the discounted marginal utility derived from consumption tomorrow if resources are transferred by means of additional holdings of government bonds. Note that variations in the consumption tax rate over time distort the intertemporal consumption decision. More specifically, a higher consumption tax rate in the future leads *ceteris paribus* to higher consumption today at the expense of tomorrow's consumption. The fourth and fifth equations together with the Euler equation for consumption form arbitrage conditions for holdings of money and capital, respectively. The second and fifth equations determine capital accumulation. They state that the expected marginal return of an additional unit of capital must equal the value of foregone consumption. Without adjustment costs

($q \equiv 1$, $\Psi \equiv 1$) the equation looks more familiar. In particular, a combination with equation three implies the common equation for the equity premium.

2.2 Firms

The product market is monopolistic competitive. Firm $j \in [0,1]$ produces good Y_{jt} employing labour N_{jt} and capital K_{jt-1}. Total factor productivity Z_t is independent of the firm and its log-deviation from the steady-state value follows an AR(1)-process:

$$\hat{Z}_{t+1} = \rho^z \hat{Z}_t + \varepsilon^z_{t+1} \ , \ \ \varepsilon^z_{t+1} \sim N(0, \sigma^z) \ , \ \ E(Z_t) = 1 \ .$$

Trend growth is driven by Harrod-neutral labour-augmenting technological progress:

$$A_{t+1} = aA_t \ , \ \ a \geq 1 \ .$$

Summing up, output of firm j is

$$Y_{jt} = Z_t (A_t N_{jt})^{\alpha} K^{1-\alpha}_{jt-1} \ , \ \ \alpha \in (0,1) \ .$$

Good Y_{jt} can be used either for investment or for consumption. For simplicity, it is assumed that all components of aggregate demand Y_t (ie private consumption, government purchases of goods, and investment) have the same demand elasticity ε. Thus, firm j faces the following demand schedule:

$$Y_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\varepsilon} Y_t \ .$$

Let π denote the steady-state value of the inflation rate. Price adjustments incur costs (see Hairault and Portier (1993)):

$$\Psi^p_{jt} = \frac{\psi^p}{2} \left(\frac{P_{jt}}{P_{jt-1}} - \pi \right)^2 A_t \ , \ \ \psi^p \geq 0 \ .$$

It is assumed that both capital and labour are homogeneous across firms and are hired on perfectly competitive, frictionless markets. Thus, firm's gross profit is

$$\mathcal{P}_{jt} = \frac{P_{jt}}{P_t} Y_{jt} - \frac{W_t A_t}{P_t} N_{jt} - (R^s_t - 1) K_{jt-1} - \Psi^p_{jt} \ .$$

The firm pays a proportional tax on profits at tax rate $\tau^{\pi}_t \in [0,1)$. It maximises the present discounted value of profits by choosing its capital and labour input as well as the price of its good. Capital markets are assumed to be perfect. Therefore, the discount factor ρ_t is given as $\beta^t \Lambda_t / \Lambda_0$. Summing up, the firm's decision rules solve

$$\max \;\; E_0 \sum_{t=0}^{\infty} \rho_t (1-\tau_t^{\pi}) \left(\frac{P_{jt}}{P_t} Y_{jt} - \frac{W_t A_t}{P_t} N_{jt} - (R_t^s - 1) K_{jt-1} - \Psi_{jt}^p \right)$$

$$s.\ t.\;\; Y_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\varepsilon} Y_t = Z_t (A_t N_{jt})^{\alpha} K_{jt-1}^{1-\alpha} \ .$$

Let φ_t denote the Lagrange multiplier of the demand schedule. Note that in a symmetric equilibrium the prices of all goods are the same and, thus, relative prices P_{jt}/P_t equal unity. For the aggregate variables the following holds:

$$X_t = X_{jt} \;\; \text{for} \;\; X \in \{K, N, Y\} \ .$$

Aggregation of the necessary conditions of the firm's problem, therefore, leads to

$$\left(1 - \frac{\varphi_t}{1-\tau_t^{\pi}}\right)(1-\alpha)\frac{Y_t}{K_{t-1}} = R_t^s - 1 \ ,$$

$$\left(1 - \frac{\varphi_t}{1-\tau_t^{\pi}}\right)\alpha\frac{Y_t}{N_t} = \frac{W_t A_t}{P_t} \ ,$$

$$\left(1 - \frac{\varphi_t \varepsilon}{1-\tau_t^{\pi}}\right) = \psi^p \pi_t (\pi_t - \pi) - \psi^p a E \frac{\beta \Lambda_{t+1}}{\Lambda_t} \frac{(1-\tau_{t+1}^{\pi})}{(1-\tau_t^{\pi})} \pi_{t+1} (\pi_{t+1} - \pi) \ .$$

The first and second equations define the firms' capital and labour demand, respectively. They show that the marginal return of factor inputs exceeds the marginal costs by $1/(1-\varphi_t/(1-\tau_t^{\pi}))$. The last equation describes the price-setting. It implies that without adjustment costs of price-setting (as eg in the deterministic steady state) the markup is equal to $\varepsilon/(\varepsilon-1)$, ie it falls with a rising elasticity of demand. With adjustment costs the markup is time-varying. In particular, if the demand schedule moves eg because of higher government consumption, prices will be adjusted only slowly so that production increases and the markup falls. Thus, the government can temporarily mitigate the goods market distortion. Another way for the government to increase production today is to announce an increase in future profit tax rates. Furthermore, prices are set with view to the need for future price adjustments. If, for example, a downward adjustment of prices is expected for the future, price adjustment partly takes place today, leading to a fall in the markup and an expansion of output. The two equations for factor demand imply that aggregate profits are given by $\varphi_t/(1-\tau_t^{\pi})Y_t - \Psi_t^p$.

2.3 Stationary variables and log-linear approximation

The model dynamics are described by transforming all variables to stationary variables,

$$m_t = \frac{M_t}{P_t A_t} \ , \quad b_t = \frac{B_t}{P_t A_t} \ , \quad k_{t-1} = \frac{K_{t-1}}{A_t} \ , \quad \pi_t = \frac{P_t}{P_{t-1}} \ ,$$
$$\lambda_t = A_t^{\eta} \Lambda_t \ , \quad w_t = \frac{W_t}{P_t} \ , \quad x_t = \frac{X_t}{A_t} \ \text{ for other variables } \ X_t \ ,$$

and by approximating the resulting system log-linearly around the steady state as was proposed by King, Plosser and Rebelo (1988). A hat over a variable denotes the log-deviation from its deterministic steady-state value.

2.4 Monetary and fiscal policy

The government issues money M_t and bonds B_t, sets the nominal (gross) interest rate R_t on bonds, levies taxes $P_t T_t$, and purchases goods $P_t G_t$. It is assumed that monetary policy follows a Taylor-type rule

$$\hat{R}_t = \rho_\pi \hat{\pi}_t \ , \quad \rho_\pi \geq 0 \ .$$

As was described in Section 2.1 and 2.2 there are lump-sum as well as activity-dependent taxes, t_t^l and t_t^y. The activity-dependent part t_t^y comprises taxes on labour and capital income, taxes on profits and consumption taxes. More specifically, total tax receipts in stationary notation are given as

$$t_t = t_t^l + t_t^y \ \text{ with } \ t_t^y = \left((\tau_t^w \alpha + \tau_t^r (1-\alpha)) \left(1 - \frac{\varphi_t}{1-\tau_t^\pi} \right) + \frac{\tau_t^\pi \varphi_t}{1-\tau_t^\pi} \right) y_t$$
$$+ \tau_t^r \left((R_{t-1} - 1) \frac{b_{t-1}}{a \pi_t} - \delta k_{t-1} \right) - \tau_t^\pi \Psi_t^p + \tau_t^c c_t \ .$$

As will be explained somewhat further down, tax rates or government consumption have to be adjusted when the model variables deviate from their steady-state level (for example after the occurrence of a shock). Thus, the tax rates might deviate temporarily from their steady-state values τ^w, τ^r, τ^π, and τ^c. The automatic stabilisers $\hat{t}_t^s$ can be measured as the log-deviation of activity-dependent taxes, with the tax rates replaced by their steady-state value, here denoted as t_t^s, from their steady-state level t^s (note $t^s = t^y$):

$$
\begin{aligned}
\hat{t}_t^s =& \log\left(t_t^s\right) - \log(t^s) \;\text{ with} \\
t_t^s =& \left((\tau^w \alpha + \tau^r(1-\alpha)) \left(1 - \frac{\varphi_t}{1-\tau^\pi}\right) + \frac{\tau^\pi \varphi_t}{1-\tau^\pi} \right) y_t \\
&+ \tau^r \left((R_{t-1}-1)\frac{b_{t-1}}{a\pi_t} - \delta k_{t-1} \right) - \tau^\pi \Psi_t^p + \tau^c c_t \;.
\end{aligned}
$$

The (real) deficit in stationary terms is given as the sum of interest payments $(R_{t-1} - 1)\frac{b_{t-1}}{a\pi_t}$ and the primary deficit $g_t - t_t - m_t + \frac{m_{t-1}}{a\pi_t}$:

$$
d_t = (R_{t-1} - 1)\frac{b_{t-1}}{a\pi_t} + g_t - t_t - m_t + \frac{m_{t-1}}{a\pi_t}
$$

and the stationary variant of the government's flow budget constraint is

$$
b_t = \frac{b_{t-1}}{a\pi_t} + d_t \;.
$$

The fiscal policy rule is expressed in terms of deficit developments. More specifically, the deficit might be above its steady-state path if taxes are below their steady-state path due to the working of the automatic stabilisers and *vice versa*. Thus, the rule is anti-cyclical. To model different degrees of anti-cyclicality (and also to allow for pro-cyclical policy), a time-independent parameter ξ is introduced that is set by the government. This parameter links the deviation of the deficit ratio from its steady-state value, $d/y\hat{d}_t$, to the impact of the automatic stabilisers:

$$
\frac{d}{y}\hat{d}_t = -\xi \frac{t^y}{y}\hat{t}_t^s \;. \tag{2}
$$

In the special case $\xi = 0$, ie when $\hat{d}_t = 0$, the deficit grows at the rate of trend GDP. This holds, for example, if the budget is always balanced. If the automatic stabilisers are allowed to work fully ($\xi = 1$), a negative deviation of activity-dependent taxes from their steady-state path by 1% implies that the deficit ratio will deviate positively from its steady-state path by $-\frac{t^y}{y}$ percentage points, where the scaling parameter arises because of the different size of the deficit and tax receipts.

The consequences of changes in ξ for the model dynamics depend on the assumptions regarding the financing of endogenous changes in tax receipts, seignorage or interest payments. The case that Ricardian equivalence holds, ie that lump-sum taxes are adjusted, is considered as a benchmark. If the government has to cut back consumption or to raise tax rates when the deficit deviates from target, this will lead to an endogenous reaction of households and firms. The model dynamics might potentially change in these cases. Therefore, besides lump-sum taxation, the different tax rates and government consumption are also considered as possible fiscal policy instruments to fulfil the fiscal rule (2).

It should be noted that variations in the tax rates can also be interpreted as changes in the payments of transfers and subsidies. For example, a lowering of the wage tax rate might be seen as an increase in a means-dependent transfer to households. A lowering of the profit tax rate can depict a rise in subsidies to firms. Furthermore, the case that lump-sum taxes are adjusted is equivalent to the case that taxes and government consumption do not react at all as long as this does not lead to explosive debt dynamics, ie as long as the rest of the system is stable.

2.5 Steady state

The calibration of the model takes the relationships between variables into account that would hold in the steady state of the deterministic version of this economy. These can be derived from the stationary version of the model equations. The steady-state value of a variable is denoted by skipping the time index.

The Euler equation for the intertemporal substitution of consumption determines β as a function of the real net return on bonds and the growth rate of the economy. Together with the Euler equation for capital accumulation it implies that the real net return on bonds equals the real net return on capital holdings in the deterministic steady state. The Euler equation for holdings of real balances gives an equation for χ. The resource constraint of the economy links the investment ratio i/y to the ratios of private and public consumption to output. From the assumptions regarding the function Ψ it follows $\Psi(i/k) = i/k$ and $\Psi'(i/k) = 1$. Capital accumulation in the steady state gives $a - 1 + \delta = \Psi(i/k)$. The Euler equation for capital accumulation together with firms' demand for capital lead to an equation for k/y.

In the steady state the labour and capital demand are $wN/y = (1-\varphi/(1-\tau^{\pi}))\alpha$ and $R^{s}k/y = (1-\varphi/(1-\tau^{\pi}))(1-\alpha)$. The pricing equation of firms becomes $\varepsilon = (1-\tau^{\pi})/\varphi$. Substitution of the labour demand schedule of firms into the labour supply function of households leads to an equation for θ. The government's flow budget constraint establishes a link between the debt and the deficit ratio. It can also be used to calculate the ratio of lump-sum taxes to GDP given the other parameters of the equation. Summing up, the following relationships between steady-state values hold:

$$
\begin{aligned}
&\frac{a}{\beta} = \frac{1 + (1-\tau^r)(R-1)}{\pi} = 1 + (1-\tau^r)(R^s - 1 - \delta) \ , \\
&\chi = \frac{m}{c(1-\tau^c)}\left(1 - \frac{\beta}{a\pi}\right) \ , \ \ i/y = 1 - c/y - g/y \ , \ \ q = 1 \ , \\
&a - 1 + \delta = \Psi(i/k) \ , \ \ k/y = (1-\alpha)\frac{\varepsilon - 1}{\varepsilon}\left(\frac{a^\eta - \beta}{(1-\tau^r)\beta} + \delta\right) \ , \qquad (3) \\
&\frac{wN}{y} = \alpha\frac{\varepsilon - 1}{\varepsilon} \ , \ \ \theta = \frac{\alpha(1-\tau^w)\frac{\varepsilon-1}{\varepsilon}\frac{1}{N}}{c/y\,(1+\tau^c)} \ , \\
&\frac{b}{y} = \frac{a\pi}{a\pi - 1}\frac{d}{y} \ , \ \ \frac{t}{y} = (R-1)\frac{b/y}{a\pi} + \frac{g}{y} - \frac{d}{y} - \frac{a\pi - 1}{a\pi}\frac{m}{y} \ .
\end{aligned}
$$

2.6 Calibration

To show the stability properties of the model some simulations are run. For this the parameter values are calibrated. For c/y, g/y, m/y, N, and π time series means are used. The time series are west German and unified German quarterly and seasonally adjusted data for 1970-1991 and for 1991.IV-1998, respectively, combined using the TRIAN technique.[2] More specifically, y refers to GDP, c to private consumption, g to government consumption, m to M1 and N is the mean of working hours per capita (including the self-employed) divided by $16 \cdot 90$ (24 minus 8 hours times 90 days per quarter). The series for g_t is detrended by applying an HP filter with a smoothing parameter of 1600. The detrended series is used to obtain the estimates for ρ^g and σ^g. The parameters of the AR(1) process for the technology shock are set to $\rho^z = 0.93$ and $\sigma^z = 0.0046$. These values are estimates for an AR(1) process for the Solow residuum with German data purged of the influence of money supply shocks, see Maußner (2001).

The return on capital $R^s - \delta$ is set to $1.065^{1/4}$ which lies between the ex-post real annual return of three-month money market bonds and the average yearly return on the German stock index DAX in the period considered. The value for the depreciation rate, $\delta = 0.011$, is taken from Maußner (2001) and is calculated from west German data for capital and investment. The growth rate $a - 1$ is estimated as the trend growth rate of real GDP per capita, assuming an exponential trend, and $\alpha(\varepsilon - 1)/\varepsilon$ is set to the average labour share, assuming that the self-employed

[2]Data according to ESA 95. Seasonal adjustment using the Bundesbank procedure based on X12 with the exception of hours which are seasonally adjusted via the Eviews X12 procedure using multiplicative factors.

c/y	m/y	N	π	β	χ	θ
0.63	0.73	0.13	1.009	0.994	0.019	5.51
a	α	ε_k	δ	$\psi_p/2$	ε	$(R^s-\delta)^4$
1.0051	0.88	0.95	0.011	25	6.0	1.065
b/y	g/y	τ^w	τ^r	τ^π	τ^c	
0.5	0.23	0.28	0.28	0.28	0.18	

Table 1: Time series means and parameter values.

earn the average wage. The elasticity $1-\varepsilon_k = -\Psi''(i/k)i/k/\Psi'(i/k)$ of the shadow price of investment in the steady state is set to 0.05 (near the value 1/15 of Baxter and Crucini (1993)). It is assumed that the adjustment of prices that deviates from average inflation by 1% incurs costs of 0.25% of production, ie $\psi_p y/2 = 25$. The markup $\varepsilon/(\varepsilon-1)$ is set to 1.2 in line with the estimate of Linnemann (1999) for Germany.

It is assumed that the means of the different income tax rates are the same. They are set to 0.28, ie to the mean of the ratio of direct taxes and social contributions to GDP in Germany in the period considered. The mean of the consumption tax rate τ^c is set to the mean of the ratio of product taxes to private consumption, which is 0.18. In principle, it would be more appropriate to use marginal tax rates (as eg in McGrattan (1994)). However, as Jones (2002) argues for the US, there is a high correlation between average tax rates as calculated from the national accounts and marginal tax rates calculated from tax records. The debt ratio is set to 50%, which is about its average over the period considered.[3] Together with the values for π and a this implies an annual deficit ratio of about 2.8% under the steady-state version of the government's flow budget constraint.

Given these assumptions and the steady-state relationships (3), the missing parameter values (β, χ, θ) can be deduced. The parameter values and the time series means that are used in the model simulation are summarised in Table 1.

[3]The results of the simulations that are presented in Section 3.2 below remain essentially unchanged if a debt ratio of 10% or 150% is used.

3 Stability and determinacy

To show how stability and determinacy of the model's equilibrium depend on the monetary and fiscal policy parameters, ρ_π and ξ, and the means used to fulfil the fiscal policy rule (2), a series of simulations is run. The main question is whether fiscal policy influences how monetary policy has to be specified in order to ensure equilibrium stability and determinacy.

3.1 General considerations

To get an idea of what might be expected from this exercise, note first that with a balanced budget rule the equilibrium of the model is stable for reasonable values of ρ_π. In accordance with the Taylor principle it changes from stable and indeterminate to stable and determinate for a threshold value for ρ_π that depends on the model. The reason for this is the following: if, as a reaction to an increase in the inflation rate, monetary policy adjusts nominal interest rates by less than the rise in the inflation rate (passive monetary policy), the real interest rate tends to fall. This induces households to lower their savings and to increase demand, thus generating inflation pressure. Therefore, self-fulfiling inflation expectations are possible. If monetary policy raises the nominal interest rate by more than the rise in inflation (active monetary policy), the real interest rate tends to increase and the equilibrium will be determinate.

The relevant interest rate for the savings-consumption decision of the household is next period's expected real interest rate net of taxes: $E_t((1 + (1 - \tau^r_{t+1})(R_t - 1))/\pi_{t+1})$. Therefore, the link between real and nominal interest rates is not exclusively determined by monetary policy but also by other factors that influence the inflation expectations $E_t(\hat{\pi}_{t+1})$ and by the evolution of interest tax rates. Furthermore, next period's real interest rate is determined endogenously to induce an equilibrium on the capital market. Therefore, it depends in particular on the return on capital and thus on investment and labour input. Since investment and labour input are influenced by the taxation of interest and labour income, endogenous variations in the respective tax rate might change the reaction of the economy to changes in nominal interest rates by the monetary policy maker.

If the government's budget does not have to be balanced, inflation dynamics and, thus, also monetary policy influence the real value of government debt. More specifically, passive monetary policy can be used to lower the real value of outstanding bonds and to prevent explosive debt growth, see Leeper (1991). However, with the fiscal rule considered here, debt dynamics are locally stable if the rest of the system is stable. This might be explained by the following observation: Including debt dynamics augments the system of difference equations that describes the model dynamics by an additional state variable (real government debt) and an additional equation for debt dynamics (the government's flow budget constraint). In log-linearised form and taking account of the fiscal rule, the additional equation reads:

$$\hat{b}_t = \frac{1}{a\pi}\hat{b}_{t-1} - \frac{1}{a\pi}\hat{\pi}_t - \xi\frac{t^y}{b}\hat{t}^s_t \ . \tag{4}$$

The automatic stabilisers $\hat{t}^s_t$ depend on last periods debt since households pay taxes on interest payments. With the definition

$$\hat{t}^{s-}_t = \hat{t}^s_t - \frac{\tau^r(R-1)b}{a\pi t^y}\hat{b}_{t-1}$$

$\hat{t}^{s-}_t$ is independent of b_{t-1} and (4) becomes

$$\hat{b}_t = \frac{1-\xi\tau^r(R-1)}{a\pi}\hat{b}_{t-1} - \frac{1}{a\pi}\hat{\pi}_t - \xi\frac{t^y}{b}\hat{t}^{s-}_t \ .$$

Since b_{t-1} or b_t do not occur in any of the other equations that are needed to solve for the dynamics of the state variables of the model, the coefficient of $\hat{b}_{t-1}$ is the additional eigenvalue of the system.[4] This eigenvalue is stable if the absolute value of the coefficient is smaller than one, ie if

$$256.5 \approx \frac{a\pi+1}{\tau^r(R-1)} > \xi > -\frac{a\pi-1}{\tau^r(R-1)} \approx -1.8 \ .$$

A value of $\xi > 256.5$ is not realistic. Values $\xi < 0$ imply that the fiscal policy maker increases the deficit ratio in upturns and reduces it in downturns. Even though this case is shown here to demonstrate the working of the rule, it is not the relevant case. Thus, within a plausible range for ξ the fiscal policy rule makes sure that the additional eigenvalue is stable. In this respect it differs from the fiscal policy rules that are typically considered in the related literature.

If lump-sum taxes can be adjusted to fulfil the fiscal rule, Ricardian equivalence holds. Therefore, there is no connection between fiscal policy and the other equations

[4]This shows that the mechanisms at work are different from those in Leith and von Thadden (2004) even though they also focus on the relevance of Ricardian equivalence for the propagation of monetary policy. However, they discuss how fiscal policy influences the model dynamics if changes in government bonds have a wealth effect, ie if the bond equation cannot be added recursively.

of the model. Hence, with plausible values for ξ the question whether the model's equilibrium is stable and determinate is independent of the specific value of the fiscal policy parameter. This might change, however, if government consumption or tax rates are adjusted to fulfil the fiscal rule. Variations in these fiscal policy variables over time influence the decisions of private agents. Thus, Ricardian equivalence no longer holds and the systematic adjustment of fiscal policy instruments might have consequences for the propagation of monetary policy.

3.2 Simulations

The model is too complicated to solve for the eigenvalues of the relevant equation system analytically. Therefore, the regions of stability and determinacy are calculated for a grid of parameters. In the simulations the value for ρ_π varies between 0 and 2 and the value of ξ between -2 and 4. The range for ρ_π contains values for an active as well as a passive monetary policy and is empirically plausible. Given the range for ξ both the cases of a pro-cyclical fiscal policy ($\xi \leq 0$) as well as an anti-cyclical fiscal policy ($\xi \geq 0$) are allowed for. An at all times balanced budget is a special case of the parameterisation $\xi = 0$. However, $\xi = 0$ only requires that the deficit moves along its steady-state path, ie while the level might also be positive or negative the deficit grows at the steady-state growth rate of GDP. For $\xi = 1$ the deviation of the deficit from its long-run path is exclusively due to the working of the automatic stabilisers. To allow for additional pro-cyclical fiscal smoothing, values $\xi \geq 1$ are also considered. In this case there is an additional 'active' pro-cyclical fiscal policy besides the 'automatic' pro-cyclicality built into the tax system.

The results of the simulation exercise are presented in Figure 1. The parameter $\rho_\pi \in (0, 2]$ is depicted at the x-axis, $\xi \in [-2, 4]$ at the y-axis. Points, stars, and crosses mark the region of stable and determinate, stable and indeterminate, and unstable model solutions, respectively.[5] The figure shows the results for different ways to fulfil the fiscal policy rule (2), ie for an adjustment of

- lump sum taxes t^l ('Lump-sum')
- government consumption g ('Gov. consumption')
- all tax rates τ^w, τ^r, τ^π, τ^c (proportional adjustment, 'Tax rates')

[5]The results of the simulations remain essentially unchanged if a debt ratio of 10% or 150% is used.

- the consumption tax rate τ^c ('Consumption tax')
- the profit tax rate τ^π ('Profit tax')
- the wage tax rate τ^w ('Wage tax')
- the interest tax rate τ^r ('Interest tax')

In the case that lump-sum taxes are adjusted to fulfil the fiscal policy rule the Taylor principle holds if the fiscal policy parameter is not too strongly pro-cyclical (ie if $\xi > -1.8$). This result was to be expected from the reasoning above. Note that since monetary policy sets the before-tax interest rate R_t, the threshold value of ρ_π that secures determinacy under lump-sum taxation is about $1/(1-\tau^r) \approx 1.4$. When government consumption, consumption tax rates or profit tax rates are adjusted, the Taylor principle is still valid for not-too-low values of ξ. Thus, even though the endogenous adjustments of the fiscal policy instruments change the propagation of monetary policy, the effect is of minor importance for stability and determinacy.

However, when interest or wage tax rates are adjusted, the propagation of monetary policy changes significantly. More specifically, the equilibrium is indeterminate for most of the considered values for ξ if interest tax rates are used as an instrument. An intuition for this result can be given as follows: if the monetary policy maker increases the nominal interest rate on bonds sharply enough to induce an increase in next period's real interest rates, this leads to higher interest payments of the government in the next period. Thus, the government raises interest tax rates according to the fiscal rule. This offsets the impact of monetary policy on the after-tax real interest rate. Net real interest rates, however, are the relevant figure for the consumption-savings decision of households, which is key to the transmission of monetary policy in the model.

If the return from bond holdings is not taxed, the argument still holds but the change in interest taxes works only indirectly via an adjustment of the return on capital and, thus, of the real interest rate. As Figure 2(a) shows, the effect is less strong in this case and the results change. In particular, the Taylor principle might even be reversed, ie active monetary policy leads to indeterminacy, passive monetary policy to determinacy. This can also occur if wage tax rates are used as the fiscal policy instrument. The reason for this might be the following: a decrease in next period's real interest rates allows the government to lower tax rates in the next period. If wage tax rates decrease this will lead to higher labour input and, therefore, to a higher real return on capital. If interest tax rates decrease, investment and, thus, next period's capital stock increases. This increases the return on labour, too, and therefore also has a positive impact on the return on capital. Overall, the direct effect of monetary policy is offset. With a higher capital stock in the next period, however, there is also a counteracting influence on the real return on capital because of decreasing returns. As can be seen from Figure 2(b) this second effect predominates if there are no capital adjustment costs. The reason for this is that, without capital adjustment costs, investment reactions are relatively strong.

If wage tax rates are the policy instrument and the fiscal policy rule is pro-cyclical, at least one of the eigenvalues of the system changes from stable to unstable, ie a passive monetary policy implies a stable and determinate equilibrium, while an active monetary policy leads to unstable model dynamics. The same holds if there are no capital adjustment costs, the profit tax rate is used as the fiscal policy instrument, and fiscal policy is anti-cyclical (see Figure 2(b)).

In the case in which there is a proportional adjustment of all tax rates (Figure 1, upper right panel) the outcome looks relatively similar to the case in which wage tax rates are adjusted. This seems to indicate that the effects of an automatic adjustment of wage tax rates dominates those of adjustments of other tax rates.

4 Conclusion

It has been shown in the last section that the stability properties of the model under consideration depend on whether government consumption or tax rates are adjusted to fulfil the fiscal rule and on which tax rate is used as the fiscal policy instrument. Since the means of financing is an integral part of fiscal policy design it should be taken into account when discussing the properties of a specific fiscal policy rule. One important result is that the range of values of the monetary policy parameter that secures stability and determinacy of the model's equilibrium depends significantly on fiscal policy if the fiscal policy maker uses wage or interest taxes to fulfil the fiscal policy rule. If other fiscal instruments are employed, however, the requirements for monetary policy to secure stability and determinacy of the equilibrium are barely influenced.

In contrast to the related literature the fiscal rule discussed in this paper is based on the automatic stabilisers and is thus anti-cyclical. This formulation seems to be of interest also with regard to the Stability and Growth Pact. The relationship between fiscal and monetary policy in this setting differs significantly from the case of a more 'standard' fiscal rule.

In a next step the model can be extended to depict the connection between changes in fiscal policy and output fluctuations in a more realistic way. As the model stands, fiscal policy can help to smooth output fluctuations only to a very limited extent. In particular, the dampening effect of anti-cyclical government spending is partly offset because government consumption crowds out private demand due to a negative wealth effect. Given empirical evidence that in normal times public consumption can affect private consumption positively, this is sometimes seen as a major weakness of the neoclassical model. The crowding-out can be curbed but not reversed if habit persistence in consumption is allowed for, as is shown eg in Burnside, Eichenbaum and Fisher (2003). A more promising way to allow for a positive connection between government and private consumption is a proposal made by Gali, López-Salido and Vallés (2003). Essentially, they argue that the discrepancy between model and observation is due to the fact that there is still 'too much' Ricardian equivalence in the model. By introducing credit-restricted ('rule-of-thumbs') consumers they can account for a positive effect of public spending on private consumption in a New-Keynesian model similar to the one considered here.

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A Summary of model equations

With the notation $u_{it} = U_i(c_t, N_t, m_t)$ for $i = 1, 2, 3$ it can be written

$$A_t^{-1} u_{1t} = U_1(C_t, N_t, M_t/P_t)\ , \quad u_{2t} = U_2(C_t, N_t, M_t/P_t) \ \text{ and } \ A_t^{-1} u_{3t} = U_3(C_t, N_t, M_t/P_t)\ .$$

Expressed in stationary variables the equation system describing the economy can be summarised as follows:

$$\lambda_t = \frac{u_{1t}}{1+\tau_t^c}\ ,$$

$$-u_{2t} = \lambda_t(1-\tau_t^w)w_t\ ,$$

$$E_t \frac{\beta}{a} \frac{1+(1-\tau_{t+1}^r)(R_t-1)}{\pi_{t+1}} \lambda_{t+1} = \lambda_t\ ,$$

$$E_t \frac{\beta}{a} \frac{1}{\pi_{t+1}} \lambda_{t+1} = \lambda_t - u_{3t}\ ,$$

$$q_t = E_t \frac{\beta \lambda_{t+1}}{a \lambda_t} \left((1-\tau_{t+1}^r)(R_t^s - 1) + q_{t+1} \left(1 - \delta + \Psi\left(\frac{i_{t+1}}{k_t}\right)\right) - \frac{i_{t+1}}{k_t} + \tau_{t+1}^r \delta \right)\ ,$$

$$q_t = \Psi'\left(\frac{i_t}{k_{t-1}}\right)^{-1}\ ,$$

$$\alpha \left(1 - \frac{\varphi_t}{1-\tau_t^\pi}\right) y_t = w_t N_t\ ,$$

$$(1-\alpha)\left(1 - \frac{\varphi_t}{1-\tau_t^\pi}\right) y_t = (R_t^s - 1)k_{t-1}\ ,$$

$$1 - \frac{\varphi_t \varepsilon}{1-\tau_t^\pi} = \psi^p \left(\pi_t (\pi_t - \pi) - E_t \frac{\beta \lambda_{t+1}(1-\tau_{t+1}^\pi)}{\lambda_t (1-\tau_t^\pi)} \pi_{t+1} (\pi_{t+1} - \pi) \right)\ ,$$

$$a k_t = \left(1 - \delta + \Psi\left(\frac{i_t}{k_{t-1}}\right)\right) k_{t-1}\ ,$$

$$y_t = c_t + i_t + g_t + \frac{\psi^p}{2} (\pi_t - \pi)^2 y_t\ ,$$

$$d_t = (R_t - 1)\frac{b_{t-1}}{a\pi_t} + g_t - t_t - m_t + \frac{m_{t-1}}{a\pi_t}\ , \quad b_t = \frac{b_{t-1}}{a\pi_t} + d_t\ ,$$

$$\begin{aligned} t_t = t_t^l &+ \left((\tau_t^w \alpha + \tau_t^r (1-\alpha)) \left(1 - \frac{\varphi_t}{1-\tau_t^\pi}\right) + \frac{\tau_t^\pi \varphi_t}{1-\tau_t^\pi} \right) y_t \\ &+ \tau_t^r \left((R_{t-1} - 1)\frac{b_{t-1}}{a\pi_t} - \delta k_{t-1} \right) - \tau_t^\pi \Psi_t^p + \tau_t^c c_t\ , \end{aligned}$$

$$\begin{aligned} \hat{t}_t^s = \log(t_t^s) - \log(t^y)\ , \quad t_t^s = &\left((\tau^w \alpha + \tau^r(1-\alpha)) \left(1 - \tfrac{\varphi_t}{1-\tau^\pi}\right) + \tfrac{\tau^\pi \varphi_t}{1-\tau^\pi} \right) y_t \\ &+ \tau^r \left((R_{t-1} - 1) \tfrac{b_{t-1}}{a\pi_t} - \delta k_{t-1} \right) - \tau^\pi \Psi_t^p + \tau^c c_t\ , \end{aligned}$$

$$\hat{R}_t = \rho_\pi \hat{\pi}_t\ ,$$

$$\hat{d}_t = -\xi \frac{t^y}{d} \hat{t}_t^s\ .$$

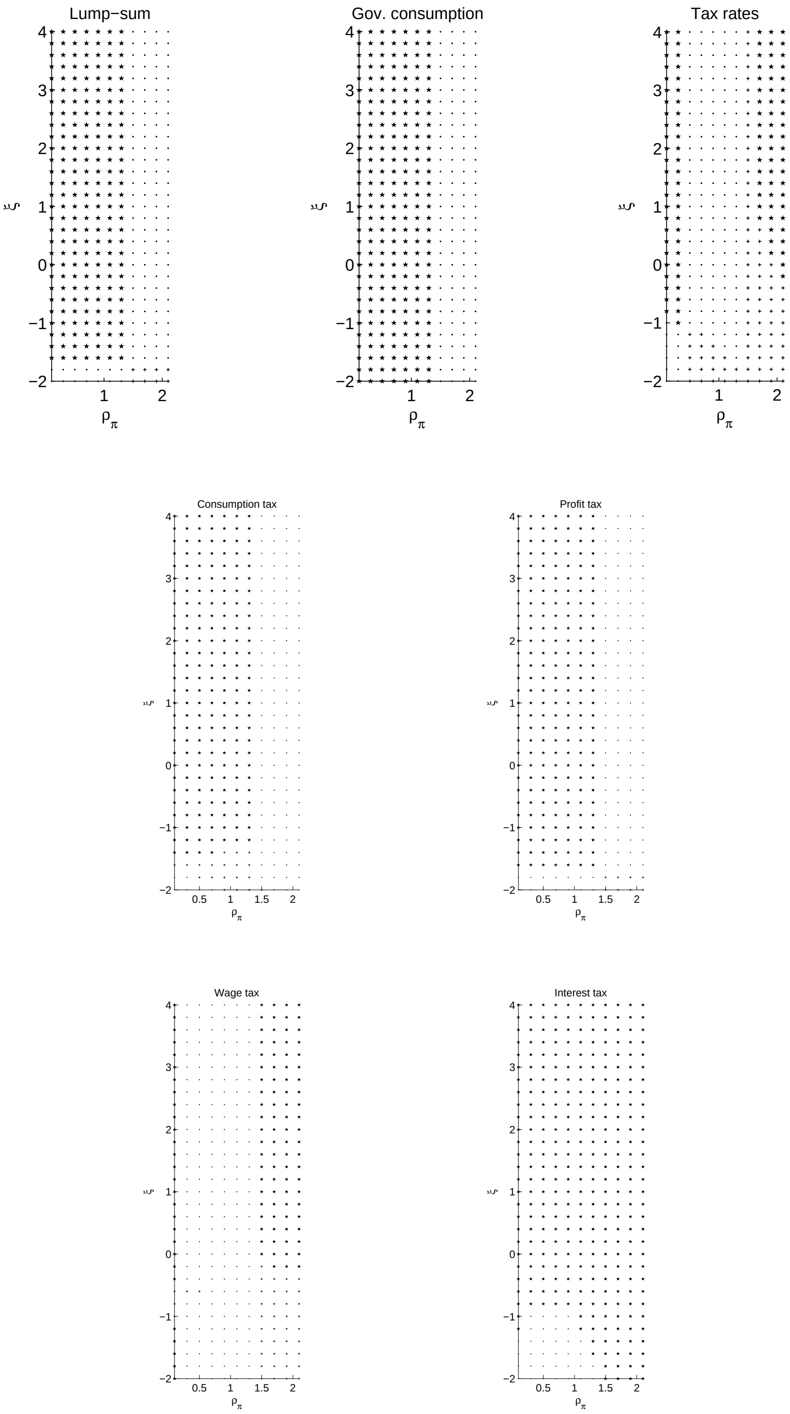
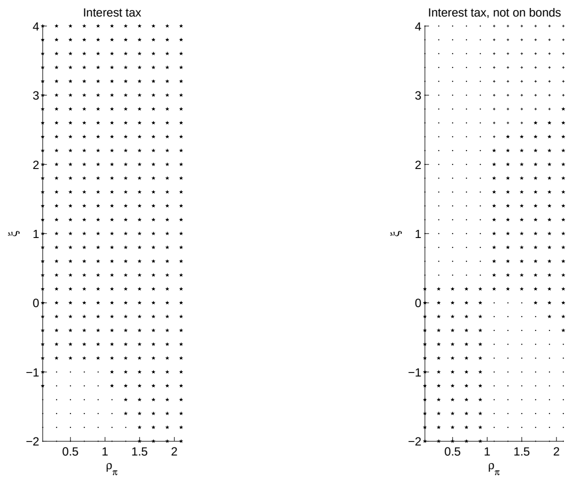
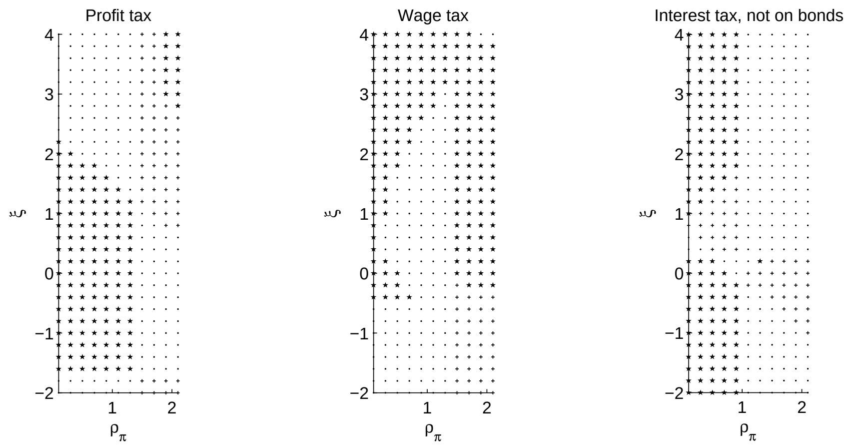


Figure 1: Stability properties for different means to fulfil the fiscal policy rule (2). Points, stars, crosses mark the region of stable and determinate, stable and indeterminate, and unstable model solutions, respectively.



(a) Interest taxes adjusted, with and without taxation of bonds.



(b) Profit, wage, and interest taxes adjusted, without capital adjustment costs.

Figure 2: Stability properties: the role of the taxation of the return on government bonds and of capital adjustment costs. Points, stars, crosses mark the region of stable and determinate, stable and indeterminate, and unstable model solutions, respectively.

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