

Railavo, Jukka

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Jukka Railavo

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EUROJÄRJESTELMÄ
EUROSYSTEMET

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Abstract

Economic and Monetary Union (EMU) can be characterised as a complicated set of legislation and institutions governing monetary and fiscal responsibilities. The measures of fiscal responsibility are to be guided by the Stability and Growth Pact (SGP), which sets rules for fiscal policy and makes a discretionary fiscal policy virtually impossible. To analyse the effects of the fiscal and monetary policy mix, we modified the New Keynesian framework to allow for supply effects of fiscal policy. We show that defining a supply-side channel for fiscal policy using an endogenous output gap changes the stabilising properties of monetary policy rules. The stability conditions are affected by fiscal policy, so that the dichotomy between active (passive) monetary policy and passive (active) fiscal policy as stabilising regimes does not hold, and it is possible to have an active monetary – active fiscal policy regime consistent with stability of the economy. We show that, if we take supply-side effects into account, we get more persistent inflation and output reactions. We also show that the dichotomy does not hold for a variety of different fiscal policy rules based on government debt and budget deficit, using the tax smoothing hypothesis and formulating the tax rules as difference equations. The debt rule with active monetary policy results in indeterminacy, while the deficit rule produces a determinate solution with active monetary policy, even with active fiscal policy. The combination of fiscal requirements in a rule results in cyclical responses to shocks. The amplitude of the cycle is larger with more weight on debt than on deficit. Combining optimised monetary policy with fiscal policy rules means that, under a discretionary monetary policy, the fiscal policy regime affects the size of the inflation bias. We also show that commitment to an optimal monetary policy not only corrects the inflation bias but also increases the persistence of output reactions. With fiscal policy rules based on the deficit we can retain the tax smoothing hypothesis also in a sticky price model.

Keywords: inflation, fiscal policy, fiscal policy rules, optimal monetary policy, policy coordination, stabilisation

Tiivistelmä

Talous- ja rahaliittoa (EMU) kuvaa monimutkainen, vastuullisuuden takaava raha- ja finanssipoliittinen rakennelma lainsäädäntöineen ja instituutioineen. Vakaus- ja kasvusopimus määrittää finanssipoliittisen vastuun asettaen finanssipoliitiikan säännöt, mistä seuraa että harkinnanvarainen finanssipoliittikka on lähes mahdotonta. Tässä tutkimuksessa arvioidaan raha- ja finanssipoliitiikan koordinaation makrotaloudellisia vaikutuksia uuskeynesiläisessä mallissa, jossa finanssipoliitikalla on myös tarjontavaikutuksia kysyntävaikutusten lisäksi. Rahapolitiikan stabilisaatio-ominaisuudet muuttuvat finanssipoliitiikan tarjontavaikutusten seurauksena. Koska finanssipoliittikkalla on suora vaikutus stabilisaatio-ominaisuuksiin, niin ei kahtiajako aktiivisen (passiivisen) raha- ja passiivisen (aktiivisen) finanssipoliitiikan talouden vakauden kanssa sopuosoinnussa olevina politiikkaregimeinä pidä enää paikkaansa, vaan talouden vakaus voidaan saavuttaa myös aktiivisen raha- ja aktiivisen finanssipoliitiikan vallitessa. Tutkimuksessa osoitetaan, että jos finanssipoliitiikan tarjontavaikutukset otetaan huomioon, inflaatio- ja tuotantovaikutukset ovat pysyvämpiä. Kahtiajako ei pidä paikkaansa myöskään erilaisilla finanssipoliitiikan säännöillä, jotka perustuvat velkaan ja alijäämään, kun verosääntö on kirjoitettu differenssimuotoon. Velkasääntö on epämääräinen aktiivisen rahapolitiikan yhteydessä riippumatta finanssipoliitikasta, kun taas alijäämsääntö tuottaa ehdottomia ratkaisuja aktiivisen raha- ja finanssipoliitiikan regimissä. Finanssipoliittisten vastuiden yhdistelmäsääntö reagoi häiriöihin aiheuttamalla syklejä. Mitä enemmän painoa velalla on suhteessa alijäämään, sitä suurempi heilahdustajuus syklillä on. Optimaalisen rahapolitiikan ja finanssipoliitiikan sääntöjen yhdistäminen aiheuttaa inflaation vääristymää, kun rahapolitiikka on harkinnanvaraista. Optimaalinen sitoutuminen rahapolitiikalla ei vain poista vinoumaa vaan myös lisää tuotannon persistenssiä. Kun finanssipoliitiikan sääntö perustuu alijäämään perustuvalla, veroasteen autokorrelaatio on lähellä ykköstä myös mallissa, jossa on hintajäykkyyttä.

Asiasanat: inflaatio, finanssipoliittikka, finanssipoliitiikan säännöt, optimaalinen rahapolitiikka, politiikkakoordinaatio, vakaus

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Chapter 1

Introduction

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1 Motivation

The final stage of Economic and Monetary Union (EMU) was the introduction of a single currency, the euro. But the EMU is more than euro notes and coins. EMU can be characterised as a complicated monetary and fiscal structure with legislation and institutions governing monetary and fiscal responsibility. Monetary policy is conducted by the European Central Bank (ECB) while fiscal policy is handled by the Member States of the European Union (EU). Therefore, the need for fiscal rules has been at the core of the debate on EMU since the early 1990s.

Article 104 of the Treaty on European Union (Maastricht) requires Member States to avoid excessive deficits. The protocol on the Excessive Deficit Procedure defines two reference values: 3% for the ratio of planned or actual government deficit to gross domestic product at market prices and 60% for the ratio of government debt to gross domestic product at market prices.¹ Article 109j of the Treaty states the economic criteria in reference to requirements of Member States of the European Union for joining the EMU. In addition to sustainability of the government financial position, there is the requirement of a high degree of price stability.²

As a result, the EMU's multilateral surveillance of national budgetary policies had to be considerably upgraded. An effective procedure for close surveillance Member States' of budgetary positions was set out in the Stability and Growth Pact (SGP). As required by the SGP, all Member States submitted stability and convergence programmes to the Council and European Commission at the end of 1998 and beginning of 1999. After the third stage, the Member States in the euro area present a stability programme containing medium-term public accounting objectives, which are updated each year to maintain the multilateral surveillance. The Member States outside of the euro area drew up convergence programmes. As stated in the first Public Finances in EMU - 2000 (EC 2000) report, a low public debt and deficit help to maintain low interest rates, facilitate the task of monetary authorities in keeping inflation under

¹Comprehensive analysis on the development and functioning of the EMU and SGP can be found in eg Hughes Hallet et al (1999), Brunila et al (2001), Buti et al (2002), Fatás et al (2003) and Hughes Hallet et al (2004).

²Article 109j also requires participation in the Exchange Rate Mechanism of the European Monetary System with evaluation in terms of exchange rate fluctuations and long term interest rate levels.

control, and create a stable environment which fosters growth. This emphasises the consideration that has been given in recent years to fiscal stability as an aid to achieving the price level stability in Europe, which is reported on annually in Public Finances in EMU reports.³

The debate on the SGP in Europe is one sign of the importance of coordinating fiscal policy and monetary policy. Central banks in many other countries are also facing the question of how extensively their decision-making process should take into consideration the behaviour of other policy makers (Herrmann 2004). There is a growing literature in monetary policy and public finance that focuses on fiscal and monetary policy coordination.

The SGP gives rules for fiscal policy and makes discretionary fiscal policy virtually impossible. The debate on fiscal rules in EMU has focused on numerical target values for government deficits and debt, not on their possible implications. There are also extensive ongoing discussions on the need for fiscal policy rules in EMU, but they seldom delve into stabilising properties of fiscal rules or the dynamics of debt and deficit. Because discretionary fiscal policy has been discredited, the stabilisation aspect of fiscal policy has concentrated on automatic stabilisers, ie on automatic fiscal policy spending (demand) shocks. In the three following chapters we attempt to formalise fiscal rules in a dynamic general equilibrium model framework and look at the implications for the economy. For a discussion and review of fiscal policy rules in theoretical models see eg Beetsma (2001) and Johnson (2001).

In the public finance literature, one of the most important recognitions is that fiscal and monetary policies are linked through the government budget constraint. Hence variations in the inflation rate can have implications for the fiscal authority's decisions on expenditure and taxes, and decisions by the fiscal authority can have implications for inflation (Walsh 2003, Chapter 4). Therefore like in Woodford (2001), the analysis should be based on the real value of outstanding government debt (given that much of public debt is nominal) in order not to neglect an important channel for fiscal effects of monetary policy.

The link between monetary and fiscal policy is not motivated solely by EMU or SGP. The link has been neglected in the monetary policy literature over the years. The literature has only recently been rejoined to emphasise the link between monetary and fiscal policy,

³EC (2000, 2001, 2002, 2003 and 2004).

which was reintroduced already in Sargent and Wallace's (1981) 'unpleasant monetary arithmetic'. They stated that monetary policy is not be able to control evolution of the price level by itself and needs to be supported by fiscal policy. Sargent and Wallace relay on the reborn concept of Ricardian equivalence (Barro 1974) where fiscal stimulus is ineffective. This was followed by tax smoothing (Barro 1979), as discretionary action was replaced by rules for both monetary and fiscal policy. For a discussion of monetary policy rules, see eg Clarida, Galí and Gertler (1999), and for a specific but widely used monetary policy rule, see Taylor (1993). Monetary policy decisions should be based on the correct measure of output. Benigno and Woodford (2004a and 2004b) consider appropriate stabilisation objectives using a model in which the output target is defined to respond to real disturbances and hence also to policy measures.

The literature on the fiscal theory of the price level (FTPL) uses Ricardian equivalence or claims that under certain circumstances the Ricardian equivalence does not hold and that fiscal policy affects inflation. In the extreme, the FTPL literature claims that fiscal policy can determine the price level independently of monetary policy.⁴ In this spirit, Leeper (1991) explored a fiscal policy rule based on government liabilities. He derived a dichotomy result in which active fiscal policy destabilises (stabilises) the economy in the context of active (passive) monetary policy. Leith and Wren-Lewis (2000 and 2002) show that this dichotomy is heavily dependent on the ex ante assumption of a passive fiscal policy regime. They further claim that in the case of discretionary taxation a passive fiscal policy regime can be observed only ex post after the shocks have been realised.

A rapidly growing branch of the literature deal with optimal fiscal and monetary policy, where the behaviour of both fiscal and monetary authority is based on optimisation. A good survey can be found in Chari and Kehoe (1999). More recent good examples of the burgeoning literature are Benigno and Woodford (2003), Schmitt-Grohé and Uribe (2004a, 2004b) and Siu (2004). Common to these models are sticky prices, imperfect competition and a distortionary tax rate. Optimal fiscal policy does not very well describe EMU and SGP, so we concentrate on fiscal policy rules.

The New Keynesian framework applied in this study is well known. Models of this genre can be found in advanced textbooks such as

⁴More about the fiscal theory of the price level can be found in eg Woodford (1994, 1995,1996), Sims (1994), Cochrane (1998, 1999, 2001). The FTPL has also its critics, see eg Buiter (2001a, 2001b) and McCallum (2001).

Walsh (2003) and Woodford (2003). Also, it is widely accepted that this framework can be used in analysing monetary and fiscal policy effects. We modify the basic model to allow for supply effects of fiscal policy by adding a tax wedge to household labour supply. The contributions of the study are in its detailed computational analysis. The choice of forms of fiscal policy rules is made from a computational viewpoint despite the fact that they may not be the most attractive ones analytically. The results of this study can be applied to the design of models for use in policy analysis and forecasting.

In Chapter 2 we derive in detail the model used in Chapters 3 and 4. The main contribution is that we are able to show that defining a supply-side channel for fiscal policy using a distortionary tax rate and a well defined output gap, changes the stabilising properties of monetary policy rules, and the stability conditions are affected by fiscal policy. Hence we show that the dichotomy between active monetary policy and passive fiscal policy, or vice versa, being the only stabilising regime does not hold and that it is possible to have an active (or passive) monetary and fiscal policy regime consistent with stability of the economy. Also, the tax wedge created by endogenising potential output has effects on impulse responses to shocks. We show that, if we take supply-side effects into account, we get more persistent inflation and output reactions.

In Chapter 3 we formulate different fiscal policy rules based on government debt and budget deficit, using Barro's (1979) tax smoothing hypothesis and formulating the tax rules as difference equations. We revive the result in Chapter 2 that the dichotomy does not hold for a variety of different rules. We are able to show that even with an active monetary active fiscal policy regime, it is possible to achieve economic stability. We show that the debt rule with active monetary policy results in indeterminacy, while the deficit rule produces a determinate solution with active monetary policy, even with active fiscal policy. The combination of fiscal requirements in a rule results in cyclical responses to shocks. The amplitude of the cycle is larger with more weight on debt than on deficit. Also active fiscal policy creates more cyclical responses.

In Chapter 4 we combine optimised monetary policy with fiscal policy rules used in the previous chapters. We show that under discretionary monetary policy the fiscal policy regime affects the size of the inflation bias. We also show that commitment to an optimal monetary policy not only corrects the inflation bias but also increases the persistence of output reactions. With fiscal policy rules based on

the deficit we can retain the tax smoothing hypothesis also in a sticky price model.

Brief summaries of the three essays are given below.

2 Effects of the supply-side channel on stabilisation policies

In Chapter 2 we carry out stability analysis with a model in which fiscal policy has both demand and supply effects, and we compare results with the standard case of demand-only effects. We show that taking supply effects into account restricts the fiscal policy parameter range consistent with dynamic stability of the economy. We argue that allowing fiscal policy to affect both supply and demand results in more persistent inflation and output responses to demand, supply and monetary policy shocks than without the supply-side channel.

We formulate a simple closed economy New Keynesian model with endogenous labour supply, nominal rigidities and a simple description of the public sector. Only tax included in the model is an income tax which is proportional and distortionary. We use the Rotemberg (1987) model to introduce price stickiness, so that we are assuming that the goods market is monopolistically competitive. The government issues money and bonds and collects taxes for revenue, which it then spends as government consumption. Monetary policy is conducted using a Taylor (1993) interest rate rule, and fiscal policy is defined by a tax rule that responds to government liabilities (Leeper 1991).

The literature on fiscal policy rules has concentrated on the demand effects of fiscal policy. Benhabib, Schmitt-Grohé and Uribe (2001) show that the specification of demand and supply have crucial effects on stability conditions. We treat potential output as an endogenously determined variable, which defines the output gap appropriately, not simply an exogenous disturbance. In our formulation, potential output responds not only to technology but also to the fiscal variables, government spending and taxes. Therefore the supply-side represents not only price stickiness, but also the demand from fiscal policy. Hence the link between monetary and fiscal policy is more than just the link in the government budget constraint since, as in Woodford (2001), fiscal policy reactions should depend on the real government debt instead of the nominal debt.

In Chapter 2 we study the effect of the supply-side channel for fiscal policy on stabilisation policies. Using the model with this feature, we show that stability conditions depend on the interaction

between monetary policy based on the interest rate rule and fiscal policy conducted via a tax rule based on government liabilities. This results in a change in the stability conditions compared to a model with an exogenously defined output gap. The monetary and fiscal policy parameters appear in the same root of the state space representation of the model when the supply-side channel is present. Now the clear distinction in the literature between fiscal policy- and monetary policy-dominated regimes becomes unclear. Therefore neither fiscal nor monetary policy can alone determine prices.

An active fiscal policy is defined not to be constrained by budgetary conditions, whereas passive fiscal policy must generate sufficient tax revenue to balance the budget. An active monetary policy is consistent with the Taylor principle in that the interest rate reacts more than one-for-one to inflation; otherwise monetary policy is passive.

With the supply-side channel, it is possible for active fiscal policy, in conjunction with active monetary policy to stabilise the economy, contrary to the common result according to which, if both monetary and fiscal policy authorities act actively, stability is not achieved. The supply-side channel restricts the parameter range of fiscal policy to be consistent with the dynamic stability of the economy compared with the traditional case with only demand effects.

Impulse responses to shocks in the supply-side channel model are different from those with an exogenous output gap. Responses to temporary shocks are more permanent for output and inflation. Since the model has a well defined steady state, we could show that permanent shocks have both short and long run effects on output and inflation. There are no effects of a permanent shock with the exogenous potential output model, due to its forward looking nature. We feel that its important for a model to take account of supply side effects of taxation. Hence the supply-side channel creates a tax wedge and the model displays non-neutrality.

3 Stability consequences of fiscal policy rules

In Chapter 3 we analyse the stability properties of different fiscal policy rules based on government debt and budget deficit, which are given as a measures of fiscal policy performance in the Maastricht treaty. The fiscal rules relate the change (not level) in the tax rate to either debt, deficit, or both. This relates evolution of the tax rate to Barros's (1974, 1979) tax smoothing hypothesis.

Maintaining price stability requires not only commitment to an appropriate monetary policy rule, but also to an appropriate fiscal policy rule (Woodford 2001). The fiscal policy rules can be based on government liabilities, as in Leeper (1991). Woodford (2001) concludes that the fiscal policy rule based on government budget deficit, with the Taylor (1993) rule monetary policy, results in a more attractive monetary-fiscal policy regime than does the fiscal policy rule based on debt.

In Leeper (1991) monetary and fiscal policy cannot both be active or passive at the same time if a unique equilibrium is to exist. The basic finding is that, in the case where the government budget constraint is met, an active monetary policy, ie a policy that raises the nominal interest rate by more than inflation increases, can stabilise the economy and ensure uniqueness of the equilibrium.⁵ A passive monetary policy, by contrast, underreacts to inflation in that the nominal interest rate rises by less than the increase in inflation, which destabilises the economy. The dichotomy is also supported in the literature, eg in Evans and Honkapohja (2002a), who make the distinction between polar cases by assuming that fiscal policy is either active or passive ex ante. Leith and Wren-Lewis (2000 and 2002) claim that, without an assumption about fiscal policy regime, the determination as to, an active or passive fiscal policy regime is impossible a priori. What are the options for fiscal policy to fulfil the government budget constraint, and how can fiscal policy be judged active or passive?

In Chapter 3 we use a simple closed economy New Keynesian model with a public sector. Only proportional income taxes are available and they have distortionary effects. We also derive an

⁵Being constrained by the government budget constraint indicated a passive fiscal policy.

endogenous potential output that responds not only to technology shocks but also to the fiscal policy reactions, which defines the output gap appropriately and creates a supply-side channel for fiscal policy. Price stickiness is introduced using Rotemberg's (1987) approach, so that we are assuming monopolistic competition in the goods market. Monetary policy follows a Taylor (1993) interest rate rule. In the economy, there are two different type of shocks, government spending and technology shocks, which are independent of each other.

Using a model without supply-side channel for fiscal policy, one can come to a dichotomy wherein only active monetary policy passive fiscal policy or passive monetary policy active fiscal policy regimes are consistent with dynamic stability of the economy. In Chapter 3 we use a model with a supply-side channel for fiscal policy and an endogenously defined potential output and reach a different conclusion.

We show that the fiscal policy rule based on debt results in indeterminacy with active monetary policy. The debt rule results in a determinate solution only if monetary policy is passive and if the fiscal policy parameter gets a high positive or negative value. Hence, we conclude that the debt rule results in a determinate solution for passive fiscal and monetary policy, contrary to the dichotomy result.

The fiscal policy rule based on SGP definition of budget deficit results in a determinate solution for a wide range of positive parameter values consistent with active monetary policy. We claim that fiscal policy can even be active, in conjunction with an active monetary policy and still be consistent with dynamic stability of the economy. Hence we conclude that the distortionary tax rate that creates a supply side channel for policy changes the interpretation of active and passive monetary-fiscal policy regimes, and it is possible to have an active monetary-fiscal policy regime with the government deficit-based fiscal policy rule.

The SGP gives requirements for both debt-to-GDP and deficit-to-GDP ratios. By forming the fiscal policy rule which combines the two, we can say that by setting more weight on deficit than debt tends to reduce the cyclicity of the dynamic response of the economy to shocks to government spending and technology. Cyclicity also decreases as the sum of weights on debt and deficit increases. At the same time, the tax rate response to a government expenditure shock becomes so large that it reduces output also in the short run. This also happens with deficit and real deficit rules, when the value of the fiscal policy rule parameter is large enough, ie if fiscal

policy is passive and is concerned only with the stable debt-to-GDP ratio. With a passive fiscal policy, a given expansionary government spending shock actually reduces output and causes more inflation than it would with an active fiscal policy. On the other hand, low values for the fiscal policy parameter mean high initial debt which causes the tax rate to rise in the future and results in a debt driven cycle for the economy. The larger the fiscal policy parameter, the more closely the tax rate reflects the pattern of shocks.

The SGP definition of deficit performs as well as the real deficit based on the real government flow budget constraint. Responses to government spending and technology shocks are almost identical in term of output, inflation and nominal interest rates. The only differences are in the debt-to-GDP ratio and tax rate responses.

4 Monetary consequences of alternative fiscal policy rules

In Chapter 4 we analyse the monetary impact of alternative fiscal policy rules for both demand and supply shocks. The literature on monetary policy has focused on how monetary policy can stabilise the economy under shocks, mainly technology shocks. Benhabib and Wen (2004) claim that an aggregate demand shock is able to explain actual fluctuations in RBC models. From a Keynesian point of view, demand shocks are thought to be important in generating business cycles because the slow price adjustment may cause resources to be underutilised, enabling expansion of output without increases in marginal costs, in response to an increase in demand.

We use a New Keynesian model with distortionary taxation and sticky prices. We derive an endogenous potential output that reacts to fiscal policy variables and hence fiscal policy has not only demand but supply side effects. Benigno and Woodford (2004a and 2004b) consider the appropriate stabilisation objectives in a model where the output target is defined to respond to real disturbances, and so the output gap is relevant to the policy authority.

Monetary policy is conducted by an independent central bank that optimises, while the fiscal authority must follow a rule. We analyse different fiscal policy rules based on debt and deficit. As the output gap reacts to both demand and supply, this opens another determination channel for inflation bias, since fiscal policy aims at balancing a spending shock by absorbing the inflation benefits.

We show that, under discretionary monetary policy, the size of inflation bias depends on the fiscal policy regime when fiscal policy follows a rule. If the central bank is able to commit, inflation bias disappears. The stochastic simulation results show that, under central bank commitment, output persistence increases compared to the discretionary case. The result is derived using the timeless perspective approach to precommitment (Woodford 2003). What also results is that inflation and output persistence increase to reflect the economic data. However, the variability of output increases compared to the discretionary case. The fiscal policy is also compatible with commitment optimal-monetary policy and the previous result holds

also with alternative fiscal policy rules. The fiscal policy parameter and target values do not affect the persistence of inflation and output.

With the deficit rules, the autocorrelation of the tax rate is close to unity, irrespective of monetary policy regime and irrespective of fiscal policy parameters and targets. Thus we revive Barro's (1979) random walk result with the deficit rules. The tax rate changes are smooth, as the autocorrelation is close to unity for all combinations of fiscal policy parameter and deficit-to-GDP target values, with fiscal policy rules in the difference equation form with respect of tax rate. Siu (2004) states that an important result of the optimal policy literature is the prescription of policies that smooth tax distortions over time and states of nature. When governments finance stochastic government spending by taxing labour income and issuing one-period debt, state-contingent returns on that debt allow tax rates to be roughly constant, as in Lucas and Stokey (1983) and Chari, Christiano and Kehoe (1991 and 1994).

We also show that with the debt rule and high debt-to-GDP target values, the Barro result does not hold and the tax rate inherits the stochastic nature of the underlying shocks, also in a sticky price model. In contrast to Barro's (1979) random walk result, Chari, Christiano and Kehoe (1991 and 1994) show that with flexible prices these variables inherit the serial correlation of the model's underlying shocks.

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Chapter 2

Effects of the supply-side channel on stabilisation policies

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Abstract

In this chapter we introduce an application of the supply-side channel for fiscal policy to the basic New Keynesian model. We use a proportional income tax rate instead of lump sum tax and introduce the distortions of a tax wedge. We derive a closed economy forward-looking model with government consumption and endogenous labour supply decisions. Monetary policy is conducted via a Taylor interest rate rule and fiscal policy follows a simple debt rule. Model stability is analysed with fiscal policy having both demand and supply-side effects and the results are compared with the standard case with demand-only effects. We show that taking supply-side effects into account restricts the fiscal policy parameter range to be consistent with dynamic stability of the economy. We also argue that allowing fiscal policy to affect both supply and demand results in more persistent inflation and output responses to shocks, than would obtain without the supply-side channel.

1 Introduction

The recent literature on monetary economics emphasises the link between monetary and fiscal policy, as reintroduced by Sargent and Wallace's (1981) 'unpleasant monetary arithmetic'. They stated that monetary policy is not able to control the evolution of the price level by itself and needs to be supported by fiscal policy. Monetary-fiscal policy interaction is examined in a closed economy framework, eg in Chari and Kehoe (1999), as well as in the public finance literature (eg Benhabib, Schmitt-Grohé and Uribe 2001 and Schmitt-Grohé and Uribe 2002).¹ The link between monetary and fiscal policy is more extensive than merely via the government budget constraint, and fiscal policy reactions should depend on real rather than nominal government debt as in Woodford (2001).

We formulate a simple closed economy New Keynesian model with endogenous labour supply, nominal rigidities and a simple public sector. The only tax is an income tax, which is proportional and has distortionary effects. We use the Rotemberg (1987) model to introduce price stickiness and hence assume that the goods market is monopolistically competitive.

Monetary policy is conducted via a Taylor (1993) interest rate rule and fiscal policy rule is based on a tax that responds to government liabilities (Leeper 1991). The literature includes extensive discussion of the form of the interest rate rule. Surveys of monetary policy rules are found eg in Clarida, Galí and Gertler (1999) and McCallum (1999). Similar fiscal policy rules are used in Wouters and Dombrecht (2000), Andrés, Ballabriga and Vallés (2002), and Evans and Honkapohja (2002a).

The literature on fiscal policy rules has concentrated on the demand effects of fiscal policy. Benhabib, Schmitt-Grohé and Uribe (2001) show that the specification of demand and supply has crucial effects on stability conditions. We treat potential output as an endogenously determined variable that defines the output gap appropriately, rather than just as an exogenous disturbance. We define potential output to respond not only to technology but also

¹Specifically, the literature on fiscal theory of the price level has emphasised the interaction between monetary and fiscal policy (see eg Woodford 1994, 1995 and 1996 and Sims 1994). The FTPL finding is that fiscal policy can have important implications for the price level in the traditional models where prices are affected only by monetary policy. In extreme cases, fiscal policy can determine the price level independently of monetary policy.

to fiscal variables, government spending and taxes. Therefore the supply-side entails not only price stickiness but also fiscal policy effects.

In this chapter we analyse the stability of the model when fiscal policy has both demand- and supply-side effects and compare the results with the standard case of demand-only effects. We show that taking supply effects into account restricts the range of the fiscal policy parameter that is consistent with dynamic stability of the economy. We argue that allowing fiscal policy to affect both supply and demand results in more persistent inflation and output responses to demand, supply and monetary policy shocks than in the case without the supply-side channel. Use of a distortionary tax changes the output reaction compared to conventional results, due to the tax wedge. The magnitude of the difference depends on labour supply elasticity, which affects also the stability conditions.² We also discuss different monetary and fiscal policy regimes and their implications for stabilising inflation and output.

The chapter has the following structure. Section 2 gives a detailed derivation of the model, starting with the optimisation by the household and cost minimisation by the firm. We introduce the government sector and the policy rules. Section 3 presents a calibration and stability analysis of the model, as well as results of diagnostic and policy simulation. Section 4 concludes and suggests further research topics.

²For discussion on the effects of distortionary taxation on labour supply, eg Dotsey (1994), McGrattan (1994) and Ludvigson (1996).

2 The model

2.1 The household

We begin by specifying an optimization-based model. We use the money-in-the-utility function approach and assume that money yields direct utility by incorporating money balances into the agent's utility function as in Sidrauski (1967). The representative household seeks to maximise its utility function $v^1\left(c_t, \frac{M_t}{P_t}, L_t\right) + v^2(g_t)$, where utility depends of its consumption on a composite good, c_t , real money balances, $\frac{M_t}{P_t}$, leisure, L_t , and real government consumption, g_t . Upper case letters refer to nominal values and lower case to real values. The household's utility depends on both private and government consumption, which are assumed to be separable. Therefore an increase in government consumption increases the level of the household's utility but does not affect the marginal utility of the household's consumption.

Denoting labour by l_t , leisure is $L_t = 1 - l_t$; and denoting real money balances by $\frac{M_t}{P_t} = m_t$, we can write the utility function as $v^1(c_t, m_t, 1 - l_t) + v^2(g_t)$. Now we are able to write a new utility function, $u^1(c_t, m_t, l_t) + u^2(g_t)$, which depends on real consumption, real money balances, labour and government consumption. We assume that the utility function $u^1(c_t, m_t, l_t)$ is continuous, increasing and concave.

The household faces a sequence of budget constraints in nominal terms with two nominal assets; interest bearing bonds, B_t , and non-interest bearing money balances, M_t . The nominal interest rate, R_t , represents the yield on nominal bonds. The household has nominal net labour income $(1 - \tau_t)P_t w_t l_t$ and a share of firm's profits, $(1 - \tau_t)P_t \Pi_t$, where w_t is the real gross wage rate and τ_t the income tax rate. The household's flow budget constraint, in nominal terms, is

$$P_t c_t + M_t - M_{t-1} + B_t \leq (1 + R_{t-1}) B_{t-1} + (1 - \tau_t) (P_t w_t l_t + P_t \Pi_t), \quad (2.1)$$

which can be written in real terms³ as

$$c_t + m_t - (1 - \pi_t)m_{t-1} + b_t \leq (1 + r_{t-1})b_{t-1} + (1 - \tau_t)(w_t l_t + \Pi_t). \quad (2.2)$$

The household maximises the utility function

$$E_t \sum_{t=0}^{\infty} \delta^t u^1(c_t, m_t, l_t) \quad (2.3)$$

subject to equation (2.2). The household's discount factor is $\delta = \frac{1}{(1+\rho)}$, the rate of time preference $\rho > 0$ and E_t is the expectations operator conditional on information available in period t .

The first-order conditions with respect to private consumption, real money balances, labour and savings are

$$u_c^1(c_t, m_t, l_t) - \xi_t = 0, \quad (2.4)$$

$$u_m^1(c_t, m_t, l_t) - \xi_t + \delta E_t [\xi_{t+1} (1 - \pi_{t+1})] = 0, \quad (2.5)$$

$$u_l^1(c_t, m_t, l_t) + \xi_t w_t (1 - \tau_t) = 0, \quad (2.6)$$

$$\xi_t = \delta E_t \xi_{t+1} (1 + r_t), \quad (2.7)$$

where ξ is the Lagrangean multiplier for the budget constraint and subscripts indicate partial derivatives. The optimal choices must also satisfy the transversality conditions

$$\lim_{t \rightarrow \infty} \delta^t m_t = 0 \text{ and } \lim_{t \rightarrow \infty} \delta^t b_t = 0. \quad (2.8)$$

The first-order conditions yield the allocation of income between consumption and money balances. They also show how much leisure a household is willing to trade for consumption and money. We combine equations (2.4) and (2.7) to obtain

$$E_t \left[\frac{u_c^1(c_{t+1})}{u_c^1(c_t)} \right] = \frac{1}{(1 + r_t)\delta}, \quad (2.9)$$

which is the Euler condition for optimal intertemporal allocation of consumption. We combine equations (2.4), (2.5) and (2.7) and use the definition of real interest rate to replace $(1 + r_t)$ in equation (2.7):

$$u_m^1(c_t, m_t, l_t) = u_c^1(c_t, m_t, l_t) \frac{R_t}{1 + R_t}, \quad (2.10)$$

³Inflation, π_t , is defined as $\frac{P_t - P_{t-1}}{P_t} = \pi_t$, which implies that $1 - \pi_t = \frac{P_{t-1}}{P_t}$. Then real interest rate, r_t , is defined $1 + r_t = (1 + R_t)(1 - E_t \pi_{t+1})$, where R_t is nominal interest rate and $E_t \pi_{t+1}$ the expected inflation rate. This definition of inflation is consistent with the timing of government debt in the government budget constraint in Section 2.3 and the household's budget constraint.

which says that the marginal rate of substitution between money and consumption is equal to the opportunity cost of holding money. The opportunity cost is directly related to the nominal interest rate. Combining equations (2.4) and (2.6) yields the household's labour supply function

$$u_l^1(c_t, m_t, l_t) = - [u_c^1(c_t, m_t, l_t) w_t(1 - \tau_t)], \quad (2.11)$$

which states that the marginal rate of substitution between labour supply and consumption is equal to the real net wage rate.

Now we assume a periodical utility function to be $u^1(c_t, m_t, l_t) = \frac{c_t^{1-\sigma}}{1-\sigma} + \frac{\Gamma m_t^{1-\sigma}}{1-\sigma} - \frac{l_t^{1+\lambda}}{1+\lambda}$, where $\sigma \geq 0, \sigma \neq 1$ is the measure of risk aversion and Γ is a positive constant.⁴ $\lambda \geq 0$ is the inverse of the labour supply elasticity. When $\lambda = 0$, preferences are linear in labour and labour supply elasticity is infinite (Hansen (1985)). Using the periodic utility function, the Euler condition, equation (2.9), can be written as

$$c_t^{-\sigma} = E_t c_{t+1}^{-\sigma} (1 + r_t) \delta. \quad (2.12)$$

To log-linearise equation (2.12), we first take natural logarithms and rearrange using the approximation $\ln E_t c_{t+1}^{-\sigma} \approx -\sigma E_t \ln c_{t+1}$ to yield

$$\ln c_t = E_t \ln c_{t+1} - \frac{1}{\sigma} \ln(1 + r_t) - \frac{1}{\sigma} \ln \delta. \quad (2.13)$$

Equation (2.13) holds also at steady state \bar{c}_t, \bar{c}_{t+1} and \bar{r}_t . We denote with bar the steady state of a variable and with hat the logarithmic fractional deviations from the steady state. Subtracting the steady state from equation (2.13) yields

$$\ln c_t - \ln \bar{c}_t = E_t \ln c_{t+1} - \ln \bar{c}_{t+1} - \frac{1}{\sigma} [\ln(1 + r_t) - \ln(1 + \bar{r}_t)]. \quad (2.14)$$

The logarithmic deviation from steady state is then eg for consumption $\hat{c}_t = \ln\left(\frac{c_t}{\bar{c}_t}\right)$. We also use the approximation $\ln(1 + \hat{r}_t) \approx \hat{r}_t$ to write equation (2.14) in terms of deviations from steady state:

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma} \hat{r}_t. \quad (2.15)$$

⁴By writing the parameter σ for both private consumption and the real money balances in the periodical utility function we make an assumption that they grow at the same rate.

The government purchases the amount g_t of total output, which is in addition to household's consumption. An economy-wide resource constraint is

$$y_t = c_t + g_t, \quad (2.16)$$

where y_t denotes total output. The resource constraint is very strict because the increase in government consumption replaces private consumption one-for-one, which causes crowding out of private consumption given that output does not change. As in Walsh (2003, Chapter 5), we use the economy-wide resource constraint to eliminate private consumption, \hat{c}_t , from equation (2.15). Log-linearisation of equation (2.16) around steady state yields⁵

$$\hat{y}_t = \frac{\bar{c}_t}{\bar{y}_t} \hat{c}_t + \frac{\bar{g}_t}{\bar{y}_t} \hat{g}_t. \quad (2.17)$$

Next we move equation (2.17) one period forward, take expectations and solve with respect to $E_t \hat{c}_{t+1}$:

$$E_t \hat{c}_{t+1} = \frac{\bar{y}_{t+1}}{\bar{c}_{t+1}} E_t \hat{y}_{t+1} - \frac{\bar{g}_{t+1}}{\bar{c}_{t+1}} E_t \hat{g}_{t+1}. \quad (2.18)$$

We substitute the updated resource constraint, equation (2.18), into Euler equation (2.15) and eliminate the expected consumption. The Euler equation is then

$$\hat{c}_t = \frac{\bar{y}_{t+1}}{\bar{c}_{t+1}} E_t \hat{y}_{t+1} - \frac{\bar{g}_{t+1}}{\bar{c}_{t+1}} E_t \hat{g}_{t+1} - \frac{1}{\sigma} \hat{r}_t. \quad (2.19)$$

Next, we substitute the Euler equation (2.19) back into the resource constraint equation (2.17) and rearrange as

$$\begin{aligned} \hat{y}_t &= \frac{\bar{c}_t}{\bar{c}_{t+1}} \frac{\bar{y}_{t+1}}{\bar{y}_t} E_t \hat{y}_{t+1} + \frac{\bar{g}_t}{\bar{y}_t} \left[\hat{g}_t - \frac{\bar{c}_t}{\bar{c}_{t+1}} \frac{\bar{g}_{t+1}}{\bar{g}_t} E_t \hat{g}_{t+1} \right] \\ &\quad - \frac{\bar{c}_t}{\bar{y}_t} \frac{1}{\sigma} \hat{r}_t. \end{aligned} \quad (2.20)$$

The nominal growth rates must be equal in the steady state; hence $\frac{\bar{c}_t}{\bar{c}_{t+1}} = \frac{\bar{y}_t}{\bar{y}_{t+1}} = \frac{\bar{g}_t}{\bar{g}_{t+1}}$. We simplify equation (2.20) to obtain an IS curve:

$$\hat{y}_t = E_t \hat{y}_{t+1} + \frac{\bar{g}_t}{\bar{y}_t} [\hat{g}_t - E_t \hat{g}_{t+1}] - \frac{\bar{c}_t}{\bar{y}_t} \frac{1}{\sigma} \hat{r}_t, \quad (2.21)$$

⁵For details, see eg Uhlig (1999).

which is the commonly used aggregate demand equation in monetary policy literature (see eg Woodford 1999). Equation (2.21) does not include any lagged variable that affects current output, but expectations are crucial. Woodford (1999) emphasises the theoretical and empirical importance for output of the forward-looking elements. Monetary policy affects aggregate demand only to the extent that it affects deviations of the real rate from \bar{r} . Moreover, monetary policy affects aggregate demand via the expected future real interest rate instead of nominal interest rates. This has a dynamic link to expected future inflation. In order to write the aggregate demand equation in levels, we use the notation $\widehat{c}_t = \ln\left(\frac{c_t}{\bar{c}_t}\right)$ and write equation (2.21) as

$$\begin{aligned} \ln y_t = E_t \ln y_{t+1} + [\ln \bar{y}_t - \ln \bar{y}_{t+1}] + \frac{\bar{g}_t}{y_t} [\ln g_t - E_t \ln g_{t+1}] \quad (2.22) \\ - \frac{\bar{g}_t}{y_t} [\ln \bar{g}_t - \ln \bar{g}_{t+1}] - \frac{\bar{c}_t}{y_t} \frac{1}{\sigma} [r_t - \bar{r}_t]. \end{aligned}$$

Since equation (2.13) and the resource constraint hold in the steady state, we use them to write equation (2.22) more simply as

$$\ln y_t = E_t \ln y_{t+1} + \frac{\bar{g}_t}{\bar{y}_t} [\ln g_t - E_t \ln g_{t+1}] - \frac{\bar{c}_t}{\bar{y}_t} \frac{1}{\sigma} r_t - \frac{\bar{c}_t}{\bar{y}_t} \frac{1}{\sigma} \ln \delta. \quad (2.23)$$

This is the (logarithmic) level counterpart of equation (2.21), which we derived earlier.

Money demand is derived from equation (2.10) using the assumed periodic utility function

$$\Gamma m_t^{-\sigma} = c_t^{-\sigma} \frac{R_t}{1 + R_t}. \quad (2.24)$$

Note that $\frac{R_t}{1+R_t} = 1 - \frac{1}{1+R_t}$. Taking logarithms of equation (2.24) and subtracting steady state values \bar{m}_t , \bar{c}_t and $(1 + \bar{R}_t)$ yields

$$\begin{aligned} (\ln m_t - \ln \bar{m}_t) = (\ln c_t - \ln \bar{c}_t) \quad (2.25) \\ - \frac{1}{\sigma} (\ln(1 + R_t) - \ln(1 + \bar{R}_t)) + \frac{1}{\sigma} (\ln \Gamma - \ln \bar{\Gamma}). \end{aligned}$$

Since $\widehat{c}_t = \ln\left(\frac{c_t}{\bar{c}_t}\right)$, equation (2.25) yields the log-linear form⁶

$$\widehat{m}_t = \widehat{c}_t - \frac{1}{\sigma} \widehat{R}_t. \quad (2.26)$$

⁶We approximate the deviation of nominal interest rate from steady state value by $\widehat{R}_t \approx \ln(1 + R_t) - \ln(1 + \bar{R}_t)$.

We substitute the economy's resource constraint, $\widehat{c}_t = \frac{\bar{y}_t}{\bar{c}_t} \widehat{y}_t - \frac{\bar{g}_t}{\bar{c}_t} \widehat{g}_t$, into equation (2.26) to obtain

$$\widehat{m}_t = \frac{\bar{y}_t}{\bar{c}_t} \widehat{y}_t - \frac{\bar{g}_t}{\bar{c}_t} \widehat{g}_t - \frac{1}{\sigma} \widehat{R}_t, \quad (2.27)$$

which is the log-linear money demand equation. Since money is assumed to pay no interest, the opportunity cost of holding money is the nominal interest rate, R_t . If the real interest rate is constant, the opportunity cost is affected by the rate of inflation. If the price level is constant (inflation rate is zero), the forgone earnings of holding money are determined by the real interest rate. Since the price level rises with a positive inflation rate, the real value of money declines and the opportunity cost of holding money increases. In equilibrium, it is required that money demand equal money supply.

To write the money demand equation (2.27) again in log-levels, we use the notation $\widehat{m} = \ln m_t - \ln \bar{m}_t$ for real variables and $\widehat{R}_t = \ln(1 + R_t) - \ln(1 + \bar{R}_t)$ for nominal interest rate:

$$\begin{aligned} \ln m_t - \ln \bar{m}_t &= \frac{\bar{y}_t}{\bar{c}_t} [\ln y_t - \ln \bar{y}_t] - \frac{\bar{g}_t}{\bar{c}_t} [\ln g_t - \ln \bar{g}_t] \\ &\quad - \frac{1}{\sigma} [\ln(1 + R_t) - \ln(1 + \bar{R}_t)]. \end{aligned} \quad (2.28)$$

We use the steady state of the resource constraint, the steady state of equation (2.25) and the approximation of nominal interest rate $R_t \approx \ln(1 + R_t)$ to write equation (2.28) as

$$\ln m_t = \frac{\bar{y}_t}{\bar{c}_t} \ln y_t - \frac{\bar{g}_t}{\bar{c}_t} \ln g_t - \frac{1}{\sigma} R_t + \frac{1}{\sigma} \ln \Gamma, \quad (2.29)$$

which is the money demand equation in (logarithmic) levels.

Rewriting equation (2.11), using the same periodic utility function as above, and taking partial derivatives yields

$$-l_t^\lambda = -[c_t^{-\sigma} w_t (1 - \tau_t)]. \quad (2.30)$$

The household's labour supply can be expressed as

$$l_t^S = c_t^{-\frac{\sigma}{\lambda}} w_t^{\frac{1}{\lambda}} (1 - \tau_t)^{\frac{1}{\lambda}}, \quad (2.31)$$

where labour supply depends on consumption and the net wage rate. The wage elasticity of labour supply is $\frac{1}{\lambda}$.

2.2 The firm

There exists a continuum of identical firms in a monopolistically competitive goods market.⁷ A representative profit maximising firm uses linear production technology

$$y_t = Al_t, \quad (2.32)$$

where A describes technological development and is defined as $A = \zeta e^{\alpha * Time}$. The production function also defines labour demand:

$$l_t^D = \frac{y_t}{A}. \quad (2.33)$$

Nominal profits are equal to⁸

$$P_t \Pi_t = P_t y_t - P_t w_t l_t. \quad (2.34)$$

The representative firm faces a real marginal cost of

$$\begin{aligned} \frac{\partial}{\partial y_t} \left[w_t \left(\frac{y_t}{A} \right) \right] \\ = w_t \frac{1}{A} \equiv mc_t. \end{aligned} \quad (2.35)$$

The equilibrium wage, w_t , is given by the labour supply equation (2.31) and labour demand equation (2.33). Substituting the equilibrium wage, $w_t = c_t^\sigma \left(\frac{y_t}{A} \right)^\lambda (1 - \tau_t)^{-1}$, into the marginal cost equation (2.35) yields

$$c_t^\sigma \left(\frac{y_t}{A} \right)^\lambda \frac{1}{A} (1 - \tau_t)^{-1} = mc_t. \quad (2.36)$$

Taking natural logarithms of equation (2.36) yields

$$\lambda \ln y_t - (1 + \lambda) \ln A + \sigma \ln c_t - \ln(1 - \tau_t) = \ln mc_t. \quad (2.37)$$

Equation (2.37) holds also in the steady state. In order to log-linearise, we subtract steady state values and write

$$\begin{aligned} \lambda [\ln y_t - \ln \bar{y}_t] + \sigma [\ln c_t - \ln \bar{c}_t] \\ - \ln(1 - \tau_t) + \ln(1 - \bar{\tau}_t) = \ln mc_t - \ln \bar{m} \bar{c}_t. \end{aligned} \quad (2.38)$$

⁷The labour market is assumed to be fully competitive, and the assumption of identical firms implies that there is no price dispersion.

⁸As shown by Walsh (2003), nominal profits are homogeneous of degree 1 in prices, so their real value will be homogeneous of degree 0. Therefore proportional changes in the nominal money stock and prices leave the household's budget constraint unaffected and do not impact consumption and labour supply decisions.

Rewriting equation (2.38), using the notation $\hat{y}_t = \ln \frac{y_t}{\bar{y}_t}$, yields

$$\lambda \hat{y}_t + \sigma \hat{c}_t - (1 - \hat{\tau}_t) = \widehat{mc}_t. \quad (2.39)$$

We substitute the resource constraint, $\hat{c}_t = \frac{\bar{y}_t}{\bar{c}_t} \hat{y}_t - \frac{\bar{g}_t}{\bar{c}_t} \hat{g}_t$, into equation (2.39) and to obtain the marginal cost equation in deviations from steady state values:

$$\left(\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda \right) \hat{y}_t - \sigma \frac{\bar{g}_t}{\bar{c}_t} \hat{g}_t - (1 - \hat{\tau}_t) = \widehat{mc}_t. \quad (2.40)$$

A monopolistically competitive firm can choose product quantity and price. An inverse supply function measures the price that must prevail for a firm to supply a given amount of output. The supply function gives the profit maximising output at each price. The firm sets its price in equilibrium at marginal cost times mark-up.⁹ We use the resource constraint to rewrite equation (2.37) as

$$\begin{aligned} \lambda \ln y_t^* + \sigma \left[\ln \bar{c}_t - \frac{\bar{y}_t}{\bar{c}_t} \ln \bar{y}_t + \frac{\bar{g}_t}{\bar{c}_t} \ln \bar{g}_t + \frac{\bar{y}_t}{\bar{c}_t} \ln y_t^* \right. \\ \left. - \frac{\bar{g}_t}{\bar{c}_t} \ln g_t \right] - (1 + \lambda) \ln A - \ln(1 - \tau_t) = \ln mc_t. \end{aligned} \quad (2.41)$$

Rewriting we get

$$\begin{aligned} \lambda \ln y_t^* + \sigma \left[\frac{\bar{y}_t}{\bar{c}_t} \ln y_t^* - \frac{\bar{g}_t}{\bar{c}_t} \ln g_t \right] \\ - (1 + \lambda) \ln A - \ln(1 - \tau_t) \\ = \ln \frac{1}{\mu} - \sigma \ln \bar{c}_t + \sigma \frac{\bar{y}_t}{\bar{c}_t} \ln \bar{y}_t - \sigma \frac{\bar{g}_t}{\bar{c}_t} \ln \bar{g}_t \equiv \Theta, \end{aligned} \quad (2.42)$$

where the right hand side is defined with a (positive) constant Θ .¹⁰ Solving $\ln y_t^*$, we write the supply function as

$$\ln y_t^* = \frac{\sigma \frac{\bar{g}_t}{\bar{c}_t}}{\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda} \ln g_t + \frac{1 + \lambda}{\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda} \ln A + \frac{1}{\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda} \ln(1 - \tau_t), \quad (2.43)$$

where y_t^* is the flexible price level of output which we call potential output. Now the level of economy's potential output is affected

⁹In equilibrium, the nominal marginal cost equals the nominal price divided by mark-up, $MC_t = \frac{1}{\mu} P_t$, where μ is the mark-up. In real terms this is $mc_t = \frac{1}{\mu}$. Taking logs yields $\ln mc_t = \ln \frac{1}{\mu}$.

¹⁰There may be a constant level term Θ in the potential output equation. We assume that $\Theta = 0$ for convenience.

by the fiscal variables, government consumption and taxation, and by technology. An increase in government consumption expands production possibilities and increases the household's labour supply, as demonstrated in Baxter and King (1993). A decrease in taxation will also increase potential output, since the household is willing to supply more labour. The potential output equation (2.43) holds also in the steady state.

In order to derive the firm's pricing equation, we use Rotemberg's (1982a, 1982b and 1987) approach to a profit maximising firm's behaviour. In the model we assume that there are costs to the firm when it changes prices. This assumption will introduce price stickiness and reflect the empirical aspect that individual price setting is lumpy. One can take a quadratic approximation of the firm's profits around P^* , which is the path of prices a firm would charge if there were no costs of changing prices. Then a forward-looking firm sets prices by minimising the quadratic loss function

$$\frac{1}{2}E_t \sum_{j=0}^{\infty} \beta^j \left[(\ln P_{t+j} - \ln P_{t+j-1})^2 + a (\ln P_{t+j} - \ln P_{t+j}^*)^2 \right], \quad (2.44)$$

where β is the discount factor and a the adjustment cost parameter. The lower the value of a , the more costly it is to change prices. The first-order condition is

$$\ln P_t = \frac{1}{1+a+\beta} \ln P_{t-1} + \frac{\beta}{1+a+\beta} E_t \ln P_{t+1} + \frac{a}{1+a+\beta} \ln P_t^*. \quad (2.45)$$

The current price level is the weighted average of the past price level, the expected future price level, and P^* . Denoting inflation by $\pi_t = \ln P_t - \ln P_{t-1}$, we can rewrite equation (2.45) as

$$\pi_t = \beta E_t \pi_{t+1} + a (\ln P_t^* - \ln P_t). \quad (2.46)$$

Note that the long-run prices $\ln P_t^*$ are determined by the marginal cost, which is, in real terms, $\ln P_t^* - \ln P_t = \ln \mu + \ln mc_t$. Log-linearising this and equation (2.46) yields¹¹

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + a (\widehat{mc}_t).$$

Using the marginal cost equation (2.40) we can write the Phillips curve in terms of deviations from the steady state:

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + a \left[\left(\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda \right) \widehat{y}_t - \sigma \frac{\bar{g}_t}{\bar{c}_t} \widehat{g}_t - (1 - \widehat{\tau}_t) \right]. \quad (2.47)$$

¹¹We assume a time invariant mark-up, μ . Therefore the deviation from the steady state $\widehat{\mu} = 0$.

Rewriting equation (2.47), using notation $\hat{y}_t = \ln \frac{y_t}{\bar{y}_t}$ and the steady state condition of equation (2.43), we obtain the expectations, technology and tax-augmented Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + a \left[\left(\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda \right) \ln y_t - \sigma \frac{\bar{g}_t}{\bar{c}_t} \ln g_t - (1 + \lambda) \ln A - \ln(1 - \tau_t) \right], \quad (2.48)$$

which can be written as follows with the help of time t potential output, y_t^* , defined by equation (2.43):

$$\pi_t = \beta E_t \pi_{t+1} + a \left[\left(\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda \right) (\ln y_t - \ln y_t^*) \right], \quad (2.49)$$

which is the New Keynesian supply curve. Now, current inflation depends on expected future values of inflation, not on past inflation. The model resembles that in Woodford (1999), where he points out that there is an important dynamic link from expectations to the present, for both inflation and output. Leong (2002) finds support for the forward looking New Keynesian model from simulation exercises. Unlike Woodford (1999), we treat potential output, y_t^* , endogenously instead of assuming it to be an exogenous disturbance. Because fiscal policy affects potential output, inflation also reacts to fiscal policy. Later we compare the results with endogenous potential output to those obtained when potential output is exogenous.

2.3 The government

We construct the intertemporal budget constraint for the policy authority, linking debt and policy choices. We write the consolidated nominal government flow budget constraint as

$$B_t + \tau_t Y_t + M_t - M_{t-1} = (1 + R_{t-1}) B_{t-1} + G_t, \quad (2.50)$$

where B_t denotes government bonds, $\tau_t Y_t$ tax revenue, M_t nominal money balances and G_t nominal government spending. We assume that the entire government debt consists of one-period instruments. Government policy is characterised by sequences of tax rates on income, a sequence of total liabilities and a sequence of government consumption. Dividing equation (2.50) by P_t gives

$$b_t + \tau_t y_t + \frac{M_t - M_{t-1}}{P_t} = (1 + R_{t-1}) b_{t-1} \frac{P_{t-1}}{P_t} + g_t. \quad (2.51)$$

Equation (2.51) can be simplified using the same approximation as before for the real interest rate, $(1 + r_t) = (1 + R_t)(1 - E_t\pi_{t+1})$. The real flow budget constraint is then

$$b_t + \tau_t y_t + \pi_t m_{t-1} + m_t - m_{t-1} = (1 + r_{t-1}) b_{t-1} + g_t. \quad (2.52)$$

The policy authority balances the budget with new debt, b_t , tax revenue, $\tau_t y_t$, and seigniorage revenue, $(\pi_t m_{t-1} + m_t - m_{t-1})$. The intertemporal government budget constraint is

$$(1 + r) b_t \leq \sum \left(\frac{1}{1 + r_{t+i}} \right)^i (\pi_{t+i} m_{t-1+i} + m_{t+i} - m_{t-1+i} + \tau_{t+i} y_{t+i} - g_{t+i}), \quad (2.53)$$

which says that the maximum level of outstanding debt including interest payments is determined by the sum of discounted seigniorage revenues and surpluses. If the intertemporal budget constraint is not binding, the policy authority can generate tax and seigniorage revenues in excess of its current commitments. If the intertemporal budget constraint is binding, higher debt levels are feasible only through a credible commitment to larger surpluses and seigniorage in the future. Fiscal policy can rely on seigniorage funding to some extent. Schmitt-Grohé and Uribe (2002) show that even a small amount of price stickiness is sufficient to sustain a low inflation tax, and therefore the government will rely more heavily on the conventional income tax.

Adding household and government budget constraints, we obtain output as the sum of labour income and firm's profits:

$$y_t = w_t l_t + \Pi_t. \quad (2.54)$$

Therefore τ_t in the budget constraint is the income tax rate, which is same for income from both labour and profits. Due to the homogeneous nature of profits, the income tax rate has distortionary effects only through the household's labour supply decision, which is not affected by profits.

2.4 Policy rules

In the literature the role of monetary policy is to stabilise the economy using the interest rate, which is commonly set according to the Taylor

(1993) rule. Interest rate settings are based on domestic economic conditions, with a positive weights ascribed to inflation and real output. Taylor suggested that an increase in the nominal interest rate should be more than one-for-one in response to inflation. We write the interest rate rule with respect to inflation deviations from inflation target and output deviations from potential output, as is common in the literature, eg in Clarida, Galí and Gertler (1999) and McCallum (1999). The interest rate rule is then

$$R_t = \pi_t + r^* + \eta_1 (\pi_t - \pi^*) + \eta_2 (\ln y_t - \ln y_t^*), \quad (2.55)$$

where r^* is the real interest rate in the steady state, π^* the inflation target and y_t^* potential output at time t , as defined by equation (2.43). There is interaction between monetary and fiscal policy, since y_t^* is affected by fiscal policy variables. The Taylor principle is that $\eta_1 > 0$ and $\eta_2 > 0$. The larger the value of η_1 , the tighter the monetary policy. In the literature, discussions on the form of interest rate rule have emphasised simple robust rules and stabilisation properties. We use the contemporaneous-time interest rate rule which, according to Bullard and Mitra (2002), is determinate for a wider range of parameters than is a forward-looking rule.

Moreover, recent developments in monetary policy literature have emphasised the link between the degrees to which monetary and fiscal policies respond to the inflation rate, debt and macroeconomic stability. In this chapter, fiscal policy is conducted according to a debt rule for the income tax rate, used by Leeper (1991), where the policy parameter is directly incorporated into real government debt. Total government liabilities are $b_{t-1} + m_{t-1}$. We write the fiscal rule with respect to a distortionary tax rate instead of the lump sum tax used in Leeper (1991)

$$\tau_t = \tau^* + \phi [(b_{t-1} + m_{t-1}) / y_t - \psi], \quad (2.56)$$

where τ^* is the uniform tax rate and ψ is a constant parameter which can be interpreted as the debt-to-GDP target. The rule generates systematic policy responses to economic conditions. Monetary authority responses to inflation are given by the magnitude $(1 + \eta_1)$ and fiscal authority responses to debt are given by the magnitude ϕ .

3 Stabilising properties of the model

3.1 Parameters

Calibration refers to the setting of parameter values for use in stability analysis and in the standard simulation of a theoretical model at the level common in the business cycle literature. Rotemberg and Woodford (1998) estimate the risk aversion coefficient $\sigma = 0.157$ and the output coefficient in the Phillips curve at 0.024. Clarida, Galí and Gertler (2000) set $\sigma = 1$ and the output coefficient at 0.3. As shown in Bullard and Mitra (2002), the model remains determinate in the case of contemporaneous-time inflation with the Taylor rule, when the value of σ is increased from 0.157 to 1 and the output coefficient from 0.024 to 0.3. We set the risk aversion coefficient σ at 0.5 and the interest rate coefficient of the IS curve $\frac{\bar{c}_t}{\bar{y}_t} \frac{1}{\sigma} = 1.5$. We set λ at 1.5, so that the labour supply elasticity with respect to real wages is 0.67. The output coefficient in the Phillips curve $a \left(\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda \right) = 0.043$, when the adjustment cost parameter a is 0.02 and the ratio of government consumption to output is set at 0.25, so that $\frac{\bar{c}_t}{\bar{y}_t} = 0.75$ and $\frac{\bar{y}_t}{\bar{c}_t} = 1.34$. The output coefficient η_2 in the Taylor rule is set at 0.4, which is smaller than in the original Taylor (1993) rule and means that monetary authority is less interested in output than is suggested by Taylor. The inflation target π^* is 0.02 and the long-term real interest rate r^* is 0.03.

The household discount factor, δ , is 0.98, but the firm's discount rate, β , is set at unity. The income elasticity of money demand is 1.34 and the interest rate elasticity of money is 2. The ratio of money balances to GDP is equal to 0.12, since the coefficient Γ is set at 0.3. The uniform tax rate τ^* is set at 0.25 and the real debt-to-GDP target $\psi = 0.6$, which is the maximum debt-to-GDP ratio permitted under the Maastricht Treaty. These parameter values reflect the economic structure of a large economy, such as the euro area.

3.2 Debt rule with the supply-side effects

We analyse the stabilising properties of the model using the methods of Blanchard and Kahn (1980). When the model is written in state-space representation, the Blanchard and Kahn requirement for a unique solution under rational expectations is that the number of roots inside a unit circle must equal the number of non-predetermined variables. When the system possesses a unique stationary rational expectations equilibrium (REE), the system is said to be determinate. If the system is indeterminate, there are multiple stationary solutions, including sunspot solutions.

We consider the system given by output equation (2.21), real money balances equation (2.27), potential output equation (2.43), inflation equation (2.49), the government budget constraint equation (2.52), the interest rate rule equation (2.55) and the debt rule equation (2.56). Government consumption is an exogenous process. Defining

$$\begin{aligned}\widehat{X}'_t &= [\widehat{y}_t \quad \widehat{\pi}_t], \\ \widehat{x}'_t &= [\widehat{g}_t \quad \widehat{b}_t \quad \widehat{\tau}_t],\end{aligned}\tag{3.1}$$

where \widehat{X}'_t is the vector of non-predetermined variables and \widehat{x}'_t the vector of predetermined variables, the reduced form can be written as

$$A \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = B \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix},\tag{3.2}$$

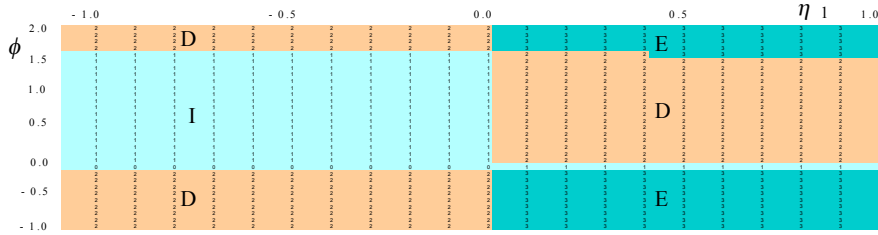
or

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = M \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix},\tag{3.3}$$

where $M = A^{-1}B$. Matrix M is defined by suitable matrices A and B as in Appendix A.

Adding the government budget constraint and fiscal rule does not increase the number of non-predetermined variables compared with a traditional three equation New Keynesian model, as eg in Bullard and Mitra (2002). The system of equation (3.3) has 2 non-predetermined variables, output and inflation $(\widehat{y}, \widehat{\pi})$. The matrix M is attached to the expectations component and should have the same number roots inside the unit circle as the system has non-predetermined variables. M is a 5×5 matrix with 5 roots and, for determinacy matrix M must have two roots inside the unit circle. Figure 1 shows the number of roots of matrix M inside the unit circle and determinate (D),

Figure 1: Determinate, indeterminate and explosive zones



indeterminate (I) and explosive (E) zones for the debt rule when the Taylor rule parameter for inflation η_1 (horizontal axis) runs from -1 to 1 and the debt rule parameter ϕ (vertical axis) runs from -1 to 2.

As we can see from Figure 1, the determinate zones are in the middle of the right hand side and in the upper and lower left hand corners. On the right hand side there exists a unique solution with the Taylor rule parameter η_1 greater than zero and values of ϕ between 0 and 1.5. According to Taylor's (1993) requirement, the interest rate should react more than one-for-one to inflation to ensure that the economy has a unique, stationary, rational expectations equilibrium. This is the Taylor principle and is labelled active monetary policy. When the fiscal authority reacts to debt with the tax rate positively but by less than a factor of 1.5, the stability of the economy can be reached via active monetary policy. As long as the monetary policy authority can affect the real interest rate through the nominal interest rate, it can affect the price level. This is possible when fiscal policy reactions are sufficiently accommodating, ie when fiscal policy parameter ϕ gets a values less than 1.5. Since there is a direct link between tax rate and inflation, the larger the values of ϕ , the greater the effect of fiscal policy on the real interest rate and the price level.

We define an active fiscal policy authority as one that is not constrained by budgetary conditions, whereas a passive fiscal authority must generate sufficient tax revenues to balance the budget. A passive decision rule depends on the current state of government debt, summarised by current and past variables, while an accommodating rule can be formed more freely using past, current or expectation variables. Fiscal policy becomes more passive (tighter) as the value of the fiscal policy parameter ϕ increases.

In the right hand side determinate zone in Figure 1 active monetary policy changes from loose to extremely tight while fiscal policy changes from active to passive and determinacy is achieved. In other words, there exists a determinate equilibrium with active monetary policy and active fiscal policy. In this zone, monetary and fiscal policy together determine prices. This conflicts with Leeper's (1991) dichotomy result that monetary and fiscal policy cannot both be active (or passive) at the same time if a determinate equilibrium is to exist.

With the inclusion of the supply-side channel for fiscal policy, the monetary policy and fiscal policy parameters appear in the same root. This makes the interaction between monetary and fiscal policy much stronger but less transparent than in the literature so far, as eg Leeper (1991) or Evans and Honkapohja (2002a). Leith and Wren-Lewis (2000) state that the distinction between monetary policy- and fiscal policy-dominated regimes depends heavily on assumptions of fiscal policy being passive a priori.¹² In addition, Leith and Wren-Lewis (2002) conclude that it is difficult to make the distinction in advance, in the manner of Evans and Honkapohja (2002a), who assume in advance that fiscal policy is passive.

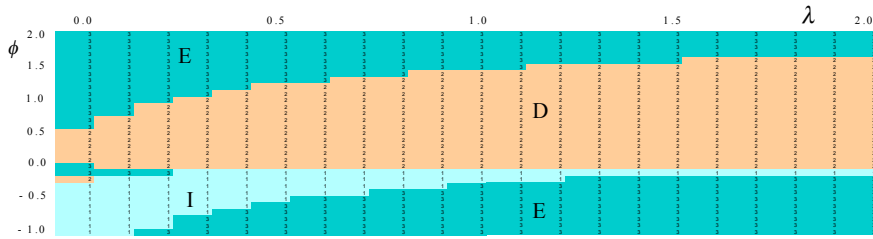
When the fiscal policy parameter, ϕ , is greater than 1.5, an increase in the tax rate affects inflation and the real interest rate enough to put the economy on an explosive path. As fiscal policy is dominant in the price level determination, monetary policy cannot stabilise the economy. This is shown in the upper right hand corner of Figure 1. When the fiscal policy parameter is negative, monetary policy is unable to stabilise the economy.

The left hand side in Figure 1 shows indeterminacy with passive monetary policy when the fiscal policy parameter values are in the range 0 to 1.5. Here, monetary policy is unable to affect the price level and fiscal policy alone is not strong enough to determine the price level. Hence there is no unique equilibrium.

Other determinate zones in Figure 1 are found where the Taylor principle does not hold. In the upper left hand corner, the fiscal parameter gets large values, which implies extremely passive fiscal policy. In the lower left hand corner, fiscal policy reacts negatively to an increase in debt. Now fiscal policy will stabilise the real interest

¹²Leith and Wren-Lewis (2000) allow their model to have deviations from Ricardian equivalence, nominal inertia in price setting, the possibility that government debt is denominated in real terms and feedback from debt disequilibrium to government spending.

Figure 2: Determinate, indeterminate and explosive zones



rate and determine the price level to ensure determinacy in both zones, as monetary policy reaction does not conflict with it.

Due to the distortionary tax rate the model exhibits non-neutrality, and changes in labour supply affect output and inflation. In addition, labour supply elasticity has an impact on stability properties. Figure 2 shows the number of roots of matrix M inside the unit circle and the determinate (D), indeterminate (I) and explosive (E) zones for the debt rule when the inverse labour supply parameter, λ , runs from 0 to 2 and the deficit rule parameter ϕ runs from -1 to 2. The Taylor rule parameter η_1 is held at 0.5. Findings in Dotsey (1994) and Ludvigson (1996) emphasise the importance of labour supply elasticity for expansionary fiscal policy. With an inelastic labour supply, Dotsey (1994) finds that a cut in the tax rate actually reduces output if the deficit is financed with proportional taxes. Ludvigson (1996) demonstrates that output may increase if labour supply is elastic, even if the deficit is to be financed by increasing proportional taxes in the future. We see that the higher the labour supply elasticity the lower the value of λ , the more readily the economy becomes indeterminate with respect of fiscal rule parameter. It is easier for the fiscal authority to finance spending with taxes when labour supply is less elastic than with infinitely elastic labour supply.

3.3 Debt rule with exogenous potential output

Stabilising properties of simple fiscal policy rules combined with monetary policy rules have been studied eg in Leeper (1991), Andrés, Ballabriga and Vallés (2002) and Evans and Honkapohja (2002a). The

traditional focus of fiscal policy has been on demand side effects, and hence the potential output has been treated as an exogenous shock variable (see eg Woodford 1999). In order to compare the results with supply-side effects to those of previous studies, we also study the determinacy of a system with exogenous potential output. We form the system similarly as above, but now without the potential output equation (2.43). The system is now given by the output equation (2.21,) real money balances equation (2.27), inflation equation (2.49), government budget constraint equation (2.52), interest rate rule equation (2.55), debt rule equation (2.56), and exogenous government consumption. We define

$$\begin{aligned}\widehat{X}'_t &= \begin{bmatrix} \widehat{y}_t & \widehat{\pi}_t \end{bmatrix}, \\ \widehat{x}'_t &= \begin{bmatrix} \widehat{g}_t & \widehat{b}_t & \widehat{\tau}_t \end{bmatrix},\end{aligned}\tag{3.4}$$

where \widehat{X}'_t is the vector with non-predetermined variables and \widehat{x}'_t is the vector of predetermined variables. The reduced form can be written

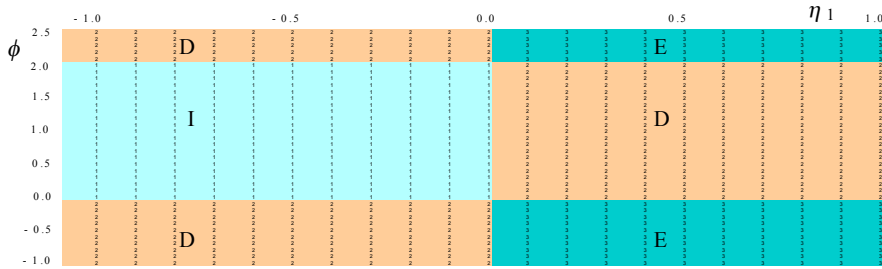
$$\mathcal{A} \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = \mathcal{B} \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix},\tag{3.5}$$

or

$$\mathcal{M} \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix},\tag{3.6}$$

where $\mathcal{M} = \mathcal{A}\mathcal{B}^{-1}$. Matrix \mathcal{M} is defined by suitable matrices \mathcal{A} and \mathcal{B} as shown in Appendix B. Matrix \mathcal{M} is now associated with contemporaneous-time variables and hence we require for determinacy that the number of roots outside the unit circle be two, since the system has 2 non-predetermined variables, output and inflation $(\widehat{y}, \widehat{\pi})$. Figure 3 shows the number of roots of matrix \mathcal{M} outside the unit circle and the determinate (D), indeterminate (I) and explosive (E) zones with a debt rule, when potential output is exogenous and fiscal policy has no supply effects. The Taylor rule inflation parameter η_1 runs from -1 to 1 and the deficit rule parameter ϕ runs from -1 to 2.5. The stabilising properties of monetary and fiscal policy differ from those with endogenous potential output. The determinate zone in the middle of the right hand side in Figure 3 is now larger than where fiscal policy has output effects (Figure 1). Fiscal policy can react more aggressively to meet the budget constraint with tax revenue instead of debt and is still able to stabilise the economy.

Figure 3: Determinate, indeterminate and explosive zones



Similarly, the indeterminate zone is larger than with endogenous potential output. When the supply-side channel is not present, fiscal policy can be more passive with active monetary policy for a determinate equilibrium to exist. This is because fiscal policy does not affect inflation and the real interest rate to the same extent as with supply-side effects. On the other hand, with negative fiscal policy parameter values the stability condition does not change. The zones shown in Figure 3 are similar to those in Evans and Honkapohja (2002a), when discount factor set at 1.

3.4 Simulation

In this section we discuss further the supply-side effects of fiscal policy. We analyse the case where fiscal policy has both demand and supply effects and compare the results with the standard case with demand-only effects. With the supply-side present, shocks have supply and demand effects. Simulation results of models with demand-only effects of fiscal policy can be found in eg Wouters and Dombrecht (2000) and Andrés, Ballabriga and Vallés (2002). They also use a policy rule to analyse the interaction between monetary and fiscal policy. Our results are similar to those of Kortelainen (2002), who uses a dynamic general equilibrium model for the euro area to analyse the credibility of monetary policy. In his model the supply-side channel is present, but he does not perform stability analysis.

In Figures 4–9 we show the responses to permanent¹³ and temporary demand, supply and monetary policy shocks. The dotted line represents the case with endogenous potential output, where fiscal policy is allowed to have supply-side effects. The solid line represents the exogenous potential output with fiscal policy having no supply-side effects. The Taylor rule parameter value η_1 is 0.5 and the fiscal policy parameter ϕ is 0.1. Figures 10–11 show the responses with supply-side effects to the temporary demand shock, with different policy parameters.

Figure 4 shows the responses of an expansionary fiscal policy to a permanent increase in government consumption amounting to 1% of GDP, which also changes the steady state of the model. When we allow fiscal policy to affect potential output through the labour supply, we observe that an increase in government consumption of 1% of GDP raises potential output by 0.4%. In the short run there is an increase in labour supply, which in the long run is reduced by the increase in the tax rate. Due to the resource constraint, government consumption substitutes for private consumption. In the long run the economy adjusts to a new equilibrium. The shock shifts resources from private sector to public sector and there are crowding-out effects of private consumption.

In response to the jump in output, the tax rate increases after the initial drop and shifts to another level. The tax-rate reaction is quite similar in both cases. With the supply-side channel present, an increase in taxes reduces net wage rate and labour supply of the household, and output decreases in the long run. Hence the fiscal policy reaction has supply-side effects. Potential output reacts more strongly than output and inflation and the nominal interest rate decreases, exhibiting non-neutrality of the model, due to distortionary taxation and endogenous labour supply. Adding supply-side effects of fiscal policy increases the disinflationary effect of a permanent fiscal shock in the short run and lowers the price level permanently. Without the supply-side channel the forward looking nature of the model does not allow for any output or inflation response to the permanent (pure) demand shock.

The impacts of a technology shock are shown in Figure 5. The technology level term, ζ , in the potential output equation is increased by 1%, and potential output is allowed to respond to the changes in other variables. In the exogenous potential output case, ie without

¹³The model has a well defined steady state and therefore we can study how permanent shocks affect the economy.

the supply-side channel for fiscal policy, the level of potential output is equivalently increased by 1% but is unaffected by changes in other variables. Real output reacts by the same amount as does potential output. As there are positive output effects, the tax rate and debt-to-GDP ratio fall further than in the case with exogenous potential output, since the increase in labour supply allows an additional tax cut, which increases output further. As a result, inflation slows and the nominal interest rate decreases slightly. All this results in an initial reaction of potential output which is twice as large as the initial shock. In the long run production converges to a new higher equilibrium level. The model exhibits non-neutrality in the case of endogenous potential output in the short run. With exogenous potential output, inflation and the interest rate are left unchanged. The demand for money will pick up following a rise in household income as labour supply increases and taxes become lower, and this leads to higher private consumption.

Figure 6 shows the effect of an increase in inflation target, which may be interpreted as a credible relaxation of monetary policy. A permanent shift of 1 percentage point in the inflation target raises actual inflation immediately by 1 percentage point. Output reacts positively as expectations of monetary policy change. A declining government debt-to-GDP ratio and hence a declining tax rate allow labour supply to grow and hence potential output and real output to increase in the long run to a higher equilibrium. As a result of a permanent shock, the debt-to-GDP ratio and tax rate converge to a new lower equilibrium. The nominal interest rate reacts more strongly in the short run than inflation in response to the positive output gap. In the long run, inflation and the nominal interest rate are linked together. Demand for money decreases as the interest rate increases and the opportunity cost of holding money rises. With endogenous potential output, inflation increases initially slightly more than in the case of exogenous potential output, where there is an equal increase in inflation and the interest rate while output remains unchanged.

Figures 7, 8 and 9 show the above shocks, respectively, when they are temporary (only one period long). The shocks show clearly the impact of the supply-side channel and the non-neutrality effect caused by the endogenous labour supply. The initial responses are almost as large in both cases, but convergence is slower with the supply-side channel.

A temporary government consumption shock will increase output, inflation and the interest rate immediately. The debt-to-GDP ratio

and tax rate will decrease initially, but jump up and converge to the equilibrium from positive values. As the tax rate increases, potential output will drop after the initial jump and follow a more persistent inflation path. The increase in government spending has inflationary effects. The channel from taxes to supply and inflation causes more permanent effects also on demand. The real output losses are larger than without the supply-side channel of fiscal policy, as the labour supply reacts to a rise in taxation and output potential decreases.

A 1% positive shock to technology will reduce inflation and the interest rate as output increases. The debt-to-GDP ratio and taxes are reduced. In the long run all variables will converge back to the baseline. Now the supply-side channel will again indicate more persistent reactions. In the case of endogenous potential output, the tax rate and debt-to-GDP ratio decrease more and real output remains above the baseline for a longer time than if potential output were fixed. The gain from lower inflation and price level is also larger.

A raise in the inflation target increases actual inflation initially by only a few tenths of a percentage point. The nominal interest rate however drops by about 0.3 percentage point, allowing output to increase as the real interest rate decreases. As a result, both output and inflation increase, since the output gap widens. The debt-to-GDP ratio and tax rate decrease in both cases. When the supply-side channel is present, potential output becomes larger. The output gap closes in the long run and inflation converges to the target level from below. The shock reduces actual inflation, as the decrease in taxation increases the labour supply and hence wage inflation.

Figure 10 shows how different monetary policy rules respond to a temporary increase in government consumption amounting to 1% of GDP. The solid line represents the Taylor rule with inflation parameter $\eta_1 = 0.1$ (a loose monetary policy rule). The dotted line is a tighter monetary policy rule with $\eta_1 = 0.5$, which is the traditional Taylor rule case. As we see, the tighter rule allows inflation and the interest rate to increase less than does the loose rule. The change in monetary policy rule has little or no effect on output or the fiscal variables (debt and tax rate).

Responses to a change in fiscal policy rule are shown in Figure 11. The solid line represents a fiscal policy rule with parameter $\phi = 1$, which allows large changes in the tax rate, but does not allow large changes in the debt-to-GDP ratio (a tighter fiscal rule, ie passive fiscal policy). The dotted line is for a fiscal policy rule with parameter $\phi = 0.1$ (a loose fiscal rule, ie active fiscal policy). We stated earlier, based

on Leeper (1991), that passive fiscal policy must keep the government budget in balance. Now we are able to make the distinction between active and passive fiscal policy ex post, and we claim that when the fiscal policy parameter value is high fiscal policy is passive. As seen from Figure 11, the debt-to-GDP ratio jumps up only for a short time and returns quickly to the baseline. With the tighter fiscal policy rule, inflation and the interest rate react more and return faster to the baseline than with the loose fiscal rule. Also, passive fiscal policy uses higher inflation taxes in the short run, but returns more quickly to the baseline, as the debt-to-GDP ratio is stabilised. The nominal interest rate reacts quite strongly when fiscal policy is tight, and losses in output are larger in the short run but remain smaller overall. The real interest rate reactions are the greater, the higher the value of the fiscal policy parameter ie the more passive the fiscal policy. Eventually, the economy can no longer stabilise.

4 Conclusions

In this chapter we studied the effect of the supply-side channel on stabilisation policies. We derived a closed economy New Keynesian model. In the model there is endogenous labour supply, distortionary income tax rate, and potential output defined so as to respond to fiscal policy variables. All this created a supply-side channel for fiscal policy. Using the model, we studied the stability conditions dependent on the interaction between a monetary policy based on an interest rate rule and fiscal policy conducted by a tax rule based on government liabilities.

We showed that the supply-side channel for fiscal policy changes the stability conditions compared to a model with an exogenously defined output gap. The monetary and fiscal policy parameters appear in the same root of the state space representation of the model when the supply-side channel is present. This made the clear distinction between the fiscal and monetary policy-dominated regimes used in the literature unclear. Therefore neither fiscal nor monetary policy can alone determine prices.

With the supply-side channel, it is possible for active fiscal policy combined with active monetary policy to stabilise the economy, contrary to the common result that says that if both monetary and fiscal policy authorities act actively, determinacy is not reached. The supply-side channel restricted the parameter range of fiscal policy consistent with the dynamic stability of the economy, as compared with the traditional case with only demand effects.

The impulse responses to shocks with the supply-side channel model are different from those with an exogenous output gap. Responses to temporary shocks are more permanent for output and inflation. Since the model has a well defined steady state, we could show that permanent shocks have both short and long run effects on output and inflation. There were no effects of a permanent shock for the exogenous potential output model, due to the forward looking nature of the model. We feel that it is important that a model take account of the supply side effects of taxation. The supply-side channel creates a tax wedge and the model displays non-neutrality of results.

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A Appendix. The system with supply-side effects of fiscal policy

The system given by the output equation (A.1), real money balances equation (A.2), inflation equation (A.3), potential output equation (A.5), interest rate rule equation (A.6), government budget constraint equation (A.7) and debt rule for tax rate equation (A.8). The government consumption equation (A.4) is an exogenous process around its steady state. We use the log-linearisation techniques¹⁴ of Uhlig (1999) to centre the government budget constraint (2.52) and tax rule (2.56) around constant steady states, and move them one period forward. We also write the Taylor rule (2.55), potential output (2.43) and Phillips curve equation (2.49) as deviations from the steady state. The system can be written as

$$\hat{y}_t = E_t \hat{y}_{t+1} + \frac{\bar{g}}{y} [\hat{g}_t - E_t \hat{g}_{t+1}] - \frac{\bar{c}}{y} \frac{1}{\sigma} (\hat{R}_t - \hat{\pi}_{t+1}) \quad (\text{A.1})$$

$$\hat{m}_t = \frac{\bar{y}}{\bar{c}} \hat{y}_t - \frac{\bar{g}}{\bar{c}} \hat{g}_t - \frac{1}{\sigma} \hat{R}_t \quad (\text{A.2})$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + a \left[\left(\sigma \frac{\bar{y}}{\bar{c}} + \lambda \right) (\hat{y}_t - \hat{y}_t^*) \right] \quad (\text{A.3})$$

$$\hat{g}_t = \hat{g}_{t+1} \quad (\text{A.4})$$

$$\hat{y}_t^* = \frac{\sigma \frac{\bar{g}}{\bar{c}}}{\sigma \frac{\bar{y}}{\bar{c}} + \lambda} \hat{g}_t - \frac{1}{\sigma \frac{\bar{y}}{\bar{c}} + \lambda} \hat{\tau}_t \quad (\text{A.5})$$

$$\hat{R}_t = (1 + \eta_1) \hat{\pi}_t + \eta_2 (\hat{y}_t - \hat{y}_t^*) \quad (\text{A.6})$$

¹⁴In log-linearisation we use the notations $c_t = \bar{c}e^{\hat{c}_t} \approx \bar{c}(1 + \hat{c}_t)$ and $\tau_t y_t = \bar{\tau} \bar{y} e^{\hat{\tau}_t + \hat{y}_t} \approx \bar{\tau} \bar{y} (1 + \hat{\tau}_t + \hat{y}_t)$. By using the steady state conditions, the coefficients can be eliminated.

$$\begin{aligned}
& \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \left(\frac{1}{\bar{R} - \bar{\pi}} + 1 \right) \right] \hat{b}_t \quad (\text{A.7}) \\
+ & \frac{\bar{m}}{\bar{y}} \left(\frac{1}{\bar{\tau}} - \frac{\bar{\pi}}{\bar{\tau}} \right) \hat{m}_t + \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \frac{\bar{R}}{\bar{R} - \bar{\pi}} \right] \hat{R}_t = \\
& \hat{y}_{t+1} + \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \frac{\bar{\pi}}{\bar{R} - \bar{\pi}} + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} \right] \hat{\pi}_{t+1} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \hat{g}_{t+1} \\
& + \frac{1 \bar{m}}{\bar{\tau} \bar{y}} \hat{m}_{t+1} + \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \frac{1}{\bar{R} - \bar{\pi}} \right] \hat{b}_{t+1} + \hat{\tau}_{t+1}
\end{aligned}$$

$$\begin{aligned}
& \frac{\phi \bar{m}}{\bar{\tau} \bar{y}} \hat{m}_t + \left(1 - \frac{\bar{\tau}^*}{\bar{\tau}} - \frac{\phi \bar{m}}{\bar{\tau} \bar{y}} + \frac{\psi}{\bar{\tau}} \right) \hat{b}_t \quad (\text{A.8}) \\
= & \left(1 + \frac{\psi}{\bar{\tau}} - \frac{\bar{\tau}^*}{\bar{\tau}} \right) \hat{y}_{t+1} + \hat{\tau}_{t+1}
\end{aligned}$$

We solve the steady state tax rate by setting the steady state government budget constraint equal to the steady state debt rule. We write tax rate as

$$\bar{\tau} = \left(\frac{\bar{\pi} \bar{m}}{\bar{R} - \bar{\pi}} - \frac{\bar{g}}{\bar{y}} + \frac{1}{\phi} \bar{\tau}^* + \frac{\bar{m}}{\bar{y}} - \frac{1}{\phi} \psi \right) \frac{1}{\frac{1}{\phi} - \frac{1}{\bar{R} - \bar{\pi}}}. \quad (\text{A.9})$$

After some substitutions, we can write the 8 equation system in 5 equations. Then we write the system in state-space form. Define

$$\begin{aligned}
\hat{X}'_t &= \begin{bmatrix} \hat{y}_t & \hat{\pi}_t \end{bmatrix}, \quad (\text{A.10}) \\
\hat{x}'_t &= \begin{bmatrix} \hat{g}_t & \hat{b}_t & \hat{\tau}_t \end{bmatrix},
\end{aligned}$$

where \hat{X}'_t is the vector with non-predetermined variables and \hat{x}'_t is the vector of predetermined variables. The reduced form can be written as

$$A \begin{bmatrix} \hat{X}'_t \\ \hat{x}'_t \end{bmatrix} = B \begin{bmatrix} E_t \hat{X}'_{t+1} \\ \hat{x}'_{t+1} \end{bmatrix}, \quad (\text{A.11})$$

or

$$\begin{bmatrix} \hat{X}'_t \\ \hat{x}'_t \end{bmatrix} = M \begin{bmatrix} E_t \hat{X}'_{t+1} \\ \hat{x}'_{t+1} \end{bmatrix}, \quad (\text{A.12})$$

where $M = A^{-1}B$. The matrices A and B can be written as

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & a_{15} \\ a_{21} & a_{22} & a_{23} & 0 & a_{25} \\ 0 & 0 & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix}, B = \begin{bmatrix} b_{11} & b_{12} & b_{13} & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & 0 & 0 & 0 & b_{55} \end{bmatrix},$$

where

$$\begin{aligned}
a_{11} &= \left[1 + \frac{\bar{c}}{y} \frac{1}{\sigma} \eta_2 \right], a_{12} = \left[\frac{\bar{c}}{y} \frac{1}{\sigma} (1 + \eta_1) \right], a_{13} = - \left[\frac{\bar{g}}{y} + \frac{\bar{c}}{y} \frac{1}{\sigma} \eta_2 \frac{\sigma \frac{\bar{g}}{c}}{\sigma \frac{\bar{g}}{c} + \lambda} \right], \\
a_{15} &= \left[\frac{\bar{c}}{y} \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \frac{\bar{g}}{c} + \lambda} \right], a_{21} = \left[-a \left(\sigma \frac{\bar{y}}{c} + \lambda \right) \right], a_{22} = 1, \\
a_{23} &= \left[a \left(\sigma \frac{\bar{y}}{c} + \lambda \right) \frac{\sigma \frac{\bar{g}}{c}}{\sigma \frac{\bar{g}}{c} + \lambda} \right], a_{25} = - \left[a \left(\sigma \frac{\bar{y}}{c} + \lambda \right) \frac{1}{\sigma \frac{\bar{g}}{c} + \lambda} \right], \\
a_{33} &= 1, a_{41} = \left[\frac{\bar{m}}{y} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \left(\frac{\bar{y}}{c} - \frac{1}{\sigma} \eta_2 \right) + \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{g}}{y} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} \eta_2 \right], \\
a_{42} &= - \left[\frac{\bar{m}}{y} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \frac{1}{\sigma} (1 + \eta_1) \right] + \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{g}}{y} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} (1 + \eta_1), \\
a_{43} &= \left[\frac{\bar{m}}{y} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \left(\frac{1}{\sigma} \eta_2 \frac{\sigma \frac{\bar{g}}{c}}{\sigma \frac{\bar{g}}{c} + \lambda} - \frac{\bar{g}_t}{c_t} \right) - \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{g}}{y} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} \eta_2 \frac{\sigma \frac{\bar{g}}{c}}{\sigma \frac{\bar{g}}{c} + \lambda} \right], \\
a_{44} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{g}}{y} \right) \right) \left(\frac{1}{\bar{R}-\bar{\pi}} + 1 \right) \right], \\
a_{45} &= \left[\frac{\bar{m}}{y} \left(\frac{1}{\bar{\tau}} - \frac{\bar{\pi}}{\bar{\tau}} \right) \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \frac{\bar{g}}{c} + \lambda} + \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{g}}{y} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} \eta_2 \frac{1}{\sigma \frac{\bar{g}}{c} + \lambda} \right], \\
a_{51} &= \left[\frac{\phi}{\bar{\tau}} \frac{\bar{m}}{y} \left(\frac{\bar{y}}{c} - \frac{1}{\sigma} \eta_2 \right) \right], a_{52} = - \left[\frac{\phi}{\bar{\tau}} \frac{\bar{m}}{y} \frac{1}{\sigma} (1 + \eta_1) \right], \\
a_{53} &= \left[\frac{\phi}{\bar{\tau}} \frac{\bar{m}}{y} \left(\frac{1}{\sigma} \eta_2 \frac{\sigma \frac{\bar{g}}{c}}{\sigma \frac{\bar{g}}{c} + \lambda} - \frac{\bar{g}_t}{c_t} \right) \right], a_{54} = \left[1 - \frac{1}{\bar{\tau}} \left(\bar{\tau}^* + \psi - \phi \frac{\bar{m}}{y} \right) \right], \\
a_{55} &= \left[1 - \frac{\phi}{\bar{\tau}} \frac{\bar{m}}{y} \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \frac{\bar{g}}{c} + \lambda} \right], b_{11} = 1, b_{12} = \frac{\bar{c}}{y} \frac{1}{\sigma}, b_{13} = -\frac{\bar{g}}{y}, b_{22} = \\
\beta, b_{33} &= 1, \\
b_{41} &= \left[1 + \frac{1}{\bar{\tau}} \frac{\bar{m}}{y} \left(\frac{\bar{y}}{c} - \frac{1}{\sigma} \eta_2 \right) \right], \\
b_{42} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{g}}{y} \right) \right) \frac{\bar{\pi}}{\bar{R}-\bar{\pi}} + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{m}}{y} \frac{1}{\sigma} (1 + \eta_1) \right) \right], \\
b_{43} &= \left[\frac{1}{\bar{\tau}} \left(\frac{\bar{m}}{y} \left(\frac{1}{\sigma} \eta_2 \frac{\sigma \frac{\bar{g}}{c}}{\sigma \frac{\bar{g}}{c} + \lambda} - \frac{\bar{g}_t}{c_t} \right) - \frac{\bar{g}}{y} \right) \right], \\
b_{44} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{y} - \frac{\bar{g}}{y} \right) \right) \frac{1}{\bar{R}-\bar{\pi}} \right], \\
b_{45} &= \left[1 - \frac{1}{\bar{\tau}} \frac{\bar{m}}{y} \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \frac{\bar{g}}{c} + \lambda} \right], b_{51} = \left[1 + \frac{\psi - \bar{\tau}^*}{\bar{\tau}} \right], b_{55} = 1.
\end{aligned}$$

B Appendix. The system without supply-side effects of fiscal policy

The system is the same as above, but potential output is treated as an exogenous variable and so the potential output equation (A.5) is ignored. After substitutions, the reduced system has a state-space representation. Define

$$\widehat{X}'_t = \begin{bmatrix} \widehat{y}_t & \widehat{\pi}_t \end{bmatrix}, \quad (\text{B.1})$$

$$\widehat{x}'_t = \begin{bmatrix} \widehat{g}_t & \widehat{b}_t & \widehat{\tau}_t \end{bmatrix},$$

where \widehat{X}'_t is the vector with non-predetermined variables and \widehat{x}'_t is the vector of predetermined variables. The reduced form can be written

$$\mathcal{A} \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = \mathcal{B} \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix}, \quad (\text{B.2})$$

or

$$\mathcal{M} \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix}, \quad (\text{B.3})$$

where $\mathcal{M} = \mathcal{A}\mathcal{B}^{-1}$. Matrix \mathcal{M} is defined by suitable matrices \mathcal{A} and \mathcal{B} , which are written as

$$\mathcal{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ 0 & 0 & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 0 \end{bmatrix}, \quad \mathcal{B} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & 0 & 0 & 0 & b_{55} \end{bmatrix},$$

where

$$\begin{aligned} a_{11} &= \left[1 + \frac{\bar{c}}{y} \frac{1}{\sigma} \eta_2 \right], a_{12} = \left[\frac{\bar{c}}{y} \frac{1}{\sigma} (1 + \eta_1) \right], a_{13} = -\frac{\bar{g}}{y}, \\ a_{21} &= \left[-a \left(\sigma \frac{\bar{y}}{c} + \lambda \right) \right], a_{22} = 1, a_{33} = 1, \\ a_{41} &= \left[\frac{\bar{m}}{y} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \left(\frac{\bar{y}}{c} - \frac{1}{\sigma} \eta_2 \right) \right], a_{42} = \left[\frac{\bar{m}}{y} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \frac{1}{\sigma} (1 + \eta_1) \right], \\ a_{43} &= \left[\frac{\bar{m}}{y} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \frac{\bar{g}}{c} \right], a_{44} = \left[\left(1 + \frac{1}{\bar{\tau}} \left(\frac{\bar{m}}{\bar{\pi} y} - \frac{\bar{g}}{y} \right) \right) \left(\frac{1}{R-\bar{\pi}} + 1 \right) \right], \\ a_{51} &= \left[\frac{\phi \bar{m}}{\bar{\tau} y} \left(\frac{\bar{y}}{c} - \frac{1}{\sigma} \eta_2 \right) \right], a_{52} = - \left[\frac{\phi \bar{m}}{\bar{\tau} y} \frac{1}{\sigma} (1 + \eta_1) \right], \\ a_{53} &= - \left[\frac{\phi \bar{m} \bar{g}}{\bar{\tau} y c} \right], a_{54} = \left[1 - \frac{1}{\bar{\tau}} \left(\bar{\tau}^* + \psi - \phi \frac{\bar{m}}{y} \right) \right], \end{aligned}$$

$$\begin{aligned}
b_{11} &= 1, b_{12} = \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma}, b_{13} = -\frac{\bar{g}}{\bar{y}}, b_{22} = \beta, b_{33} = 1 \\
b_{41} &= \left[1 + \frac{1}{\bar{\tau}} \frac{\bar{m}}{\bar{y}} \left(\frac{\bar{y}}{\bar{c}} - \frac{1}{\sigma} \eta_2 \right) - \left(1 + \frac{1}{\bar{\tau}} \left(\frac{\bar{\pi} \bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{R}}{\bar{R} - \bar{\pi}} \eta_2 \right], \\
b_{42} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\frac{\bar{\pi} \bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{\pi}}{\bar{R} - \bar{\pi}} + \frac{1}{\bar{\tau}} \left(\frac{\bar{\pi} \bar{m}}{\bar{y}} - \frac{\bar{m}}{\bar{y}} \frac{1}{\sigma} (1 + \eta_1) \right) \right. \\
&\quad \left. - \left(1 + \frac{1}{\bar{\tau}} \left(\frac{\bar{\pi} \bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{R}}{\bar{R} - \bar{\pi}} (1 + \eta_1) \right], b_{43} = - \left[\frac{1}{\bar{\tau}} \left(\frac{\bar{m} \bar{g}}{\bar{y} \bar{c}} + \frac{\bar{g}}{\bar{y}} \right) \right], \\
b_{44} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\frac{\bar{\pi} \bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{1}{\bar{R} - \bar{\pi}} \right], b_{45} = 1, b_{51} = \left[1 + \frac{\psi - \bar{\tau}^*}{\bar{\tau}} \right], \\
b_{55} &= 1
\end{aligned}$$

Matrix \mathcal{A} is singular, so it has no inverse. Therefore we define matrix $\mathcal{M} = \mathcal{A}\mathcal{B}^{-1}$, which is a 5×5 matrix with five roots. Now the roots of matrix \mathcal{M} are inverses of the roots of matrix M defined in Appendix A. To avoid singularity of matrix \mathcal{A} , we could have substituted the tax rule into the system. Then the matrix \mathcal{M} would be a 4×4 matrix. The conclusions, however, would remain the same.

C Appendix. The model

C.1 The dynamic model

- 1. IS (Euler equation)

$$\ln y_t = \ln y_{t+1} + \frac{\bar{y}}{y} (\ln g_t - \ln g_{t+1}) - \frac{\bar{c}}{\bar{y}\sigma} (R_t - \pi_{t+1}) - \frac{\bar{c}}{\bar{y}\sigma} \ln \delta$$

- 2. LM

$$\ln m_t = \frac{\bar{y}}{c} \ln y_t - \frac{\bar{y}}{c} \ln g_t - \frac{1}{\sigma} R_t + \frac{1}{\sigma} \ln \Gamma$$

- 3. Phillips curve

$$\pi_t = \beta \pi_{t+1} + a \left[\left(\sigma \frac{\bar{y}}{c} + \lambda \right) (\ln y_t - \ln y_t^*) \right]$$

- 4. Potential output (supply function)

$$\ln y_t^* = \frac{1}{\left(\sigma \frac{\bar{y}}{c} + \lambda \right)} \left[\sigma \frac{\bar{y}}{c} \ln g_t + (1 + \lambda) (\ln \zeta + \alpha * Time_t) + \ln (1 - \tau_t) \right]$$

- 5. Budget constraint

$$b_t = (1 + R_{t-1} - \pi_t) * b_{t-1} - \tau_t y_t + (1 - \pi_t) m_{t-1} - m_t + g_t$$

- 6. Taylor rule

$$R_t = \pi_t + r^* + \eta_1 (\pi_t - \pi^*) + \eta_2 (\ln y_t - \ln y_t^*)$$

- 7. Tax rule

$$\tau_t = \tau^* + \phi (b_{t-1} + m_{t-1}) / y_t - \psi$$

- 8. Definition

$$\ln g_t = \ln g_{t-1} + \theta$$

- 9. Definition

$$\ln P_t = \ln P_{t-1} + \pi_t$$

- 10. Long run growth rate

$$\theta = \frac{(1+\lambda)\alpha}{\sigma+\lambda}$$

C.2 The steady state model

- 1. IS (Euler equation)

$$\bar{R} = \sigma\theta + \bar{\pi} - \ln \delta$$

- 2. LM

$$\ln \bar{m} = \frac{\bar{y}}{\epsilon} \ln \bar{y} - \frac{\bar{g}}{\epsilon} \ln \bar{g} - \frac{1}{\sigma} \bar{R} + \frac{1}{\sigma} \ln \Gamma$$

- 3. Phillips curve

$$\ln \bar{y} = \ln \bar{y}^* + \frac{(1-\beta)\bar{\pi}}{a(\sigma\frac{\bar{y}}{\epsilon} + \lambda)}$$

- 4. Potential output (supply function)

$$\ln \bar{y}^* = \frac{1}{(\sigma\frac{\bar{y}}{\epsilon} + \lambda)} \left[\sigma\frac{\bar{g}}{\epsilon} \ln \bar{g} + (1 + \lambda) (\ln \zeta + \alpha * Time) - \ln(1 - \bar{\tau}) \right]$$

- 5. Budget constraint

$$\bar{b} = \frac{\bar{g} - \bar{\tau}\bar{y} - \bar{m} \left[1 - (1 - \bar{\pi}) \frac{1}{\exp \theta} \right]}{1 - (1 + \bar{R} - \bar{\pi}) \frac{1}{\exp \theta}}$$

- 6. Taylor rule

$$\bar{\pi} = \pi^* + \frac{\sigma\theta - r^* + \ln \delta}{\eta_1}$$

- 7. Tax rule

$$\bar{\tau} = \tau^* + \frac{\phi}{\bar{y}} \frac{(\bar{b} + \bar{m})}{\exp \theta} - \psi$$

- 8. Definition

$$\ln \bar{g}_t = \ln \bar{g}_{t-1} + \theta$$

- 9. Definition

$$\ln \bar{P}_t = \ln \bar{P}_{t-1} + \bar{\pi}$$

- 10. Long run growth rate

$$\theta = \frac{(1+\lambda)\alpha}{\sigma+\lambda}$$

Figure 4: Permanent increase of 1% of real GDP in government consumption, deviations from baseline

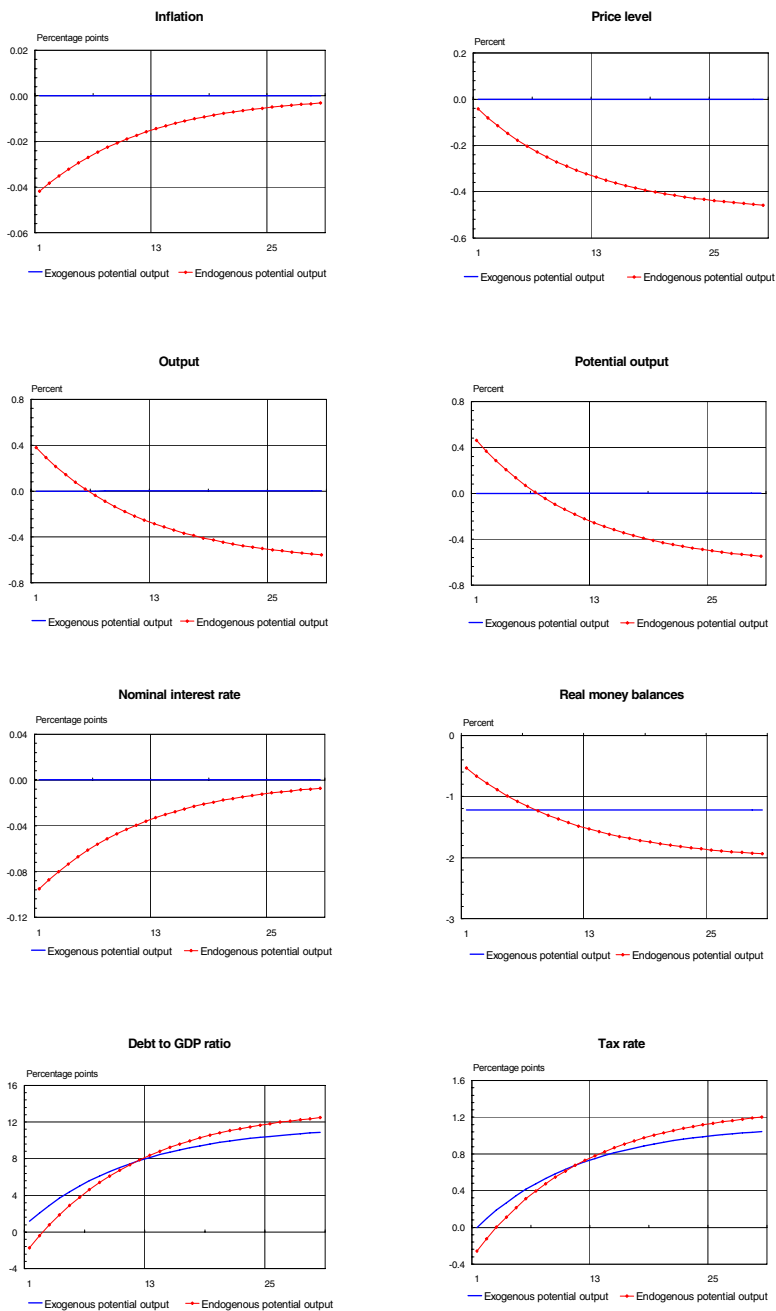


Figure 5: Permanent 1% increase in technology, deviations from baseline

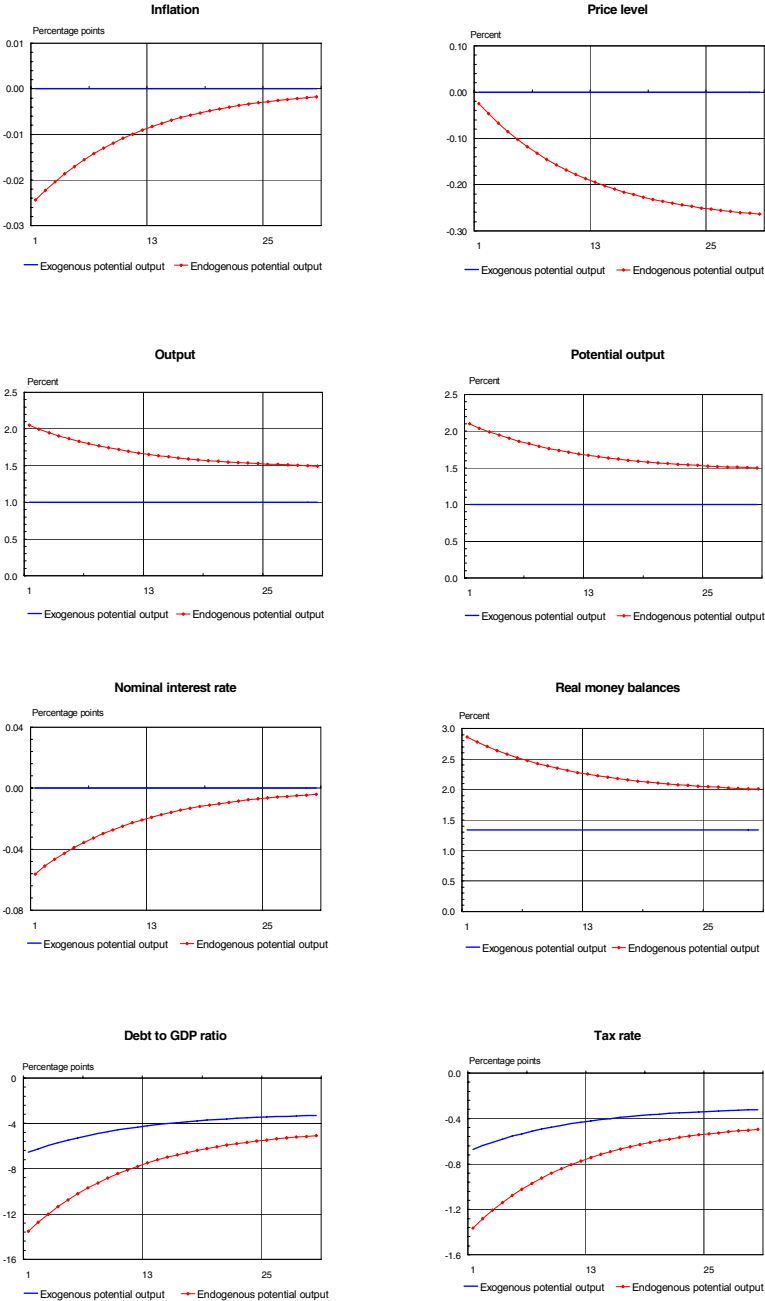


Figure 6: Permanent 1 percentage point increase in inflation target, deviations from baseline

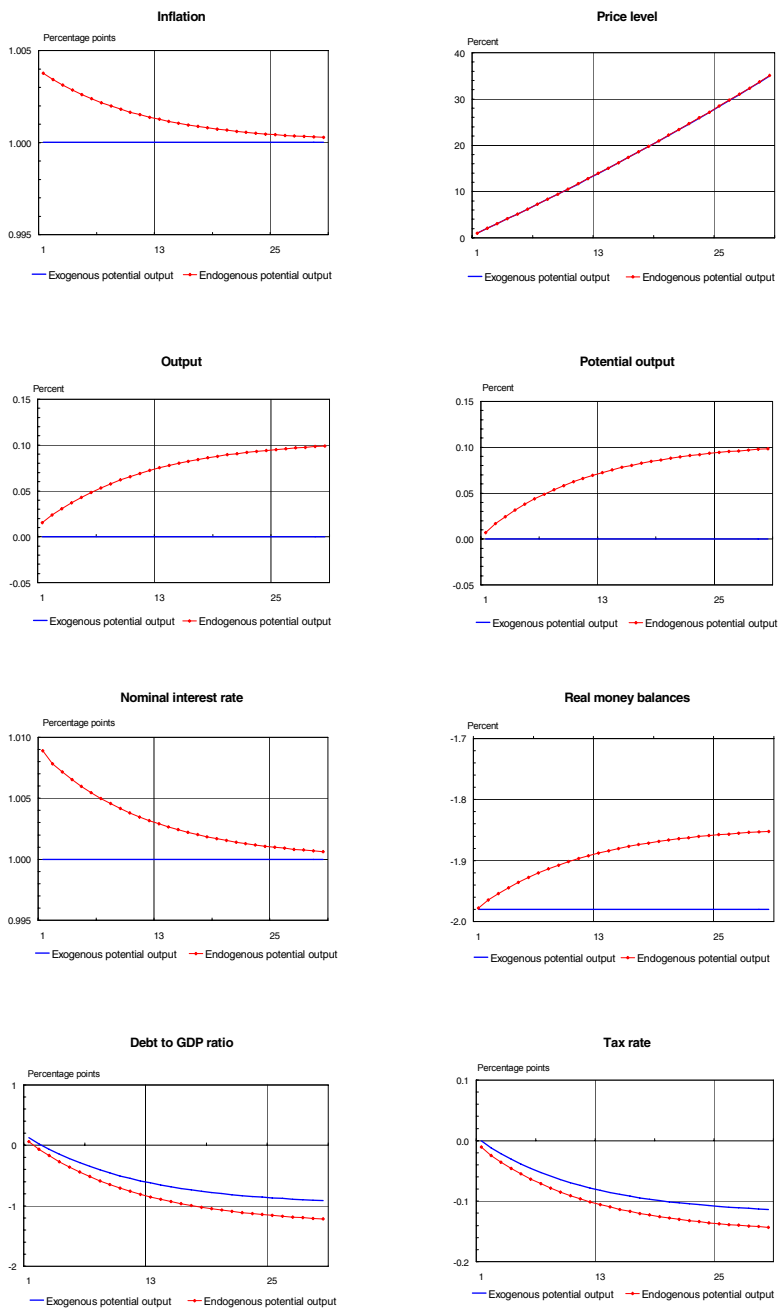


Figure 7: Temporary (one period) increase of 1% of real GDP in government consumption, deviations from baseline

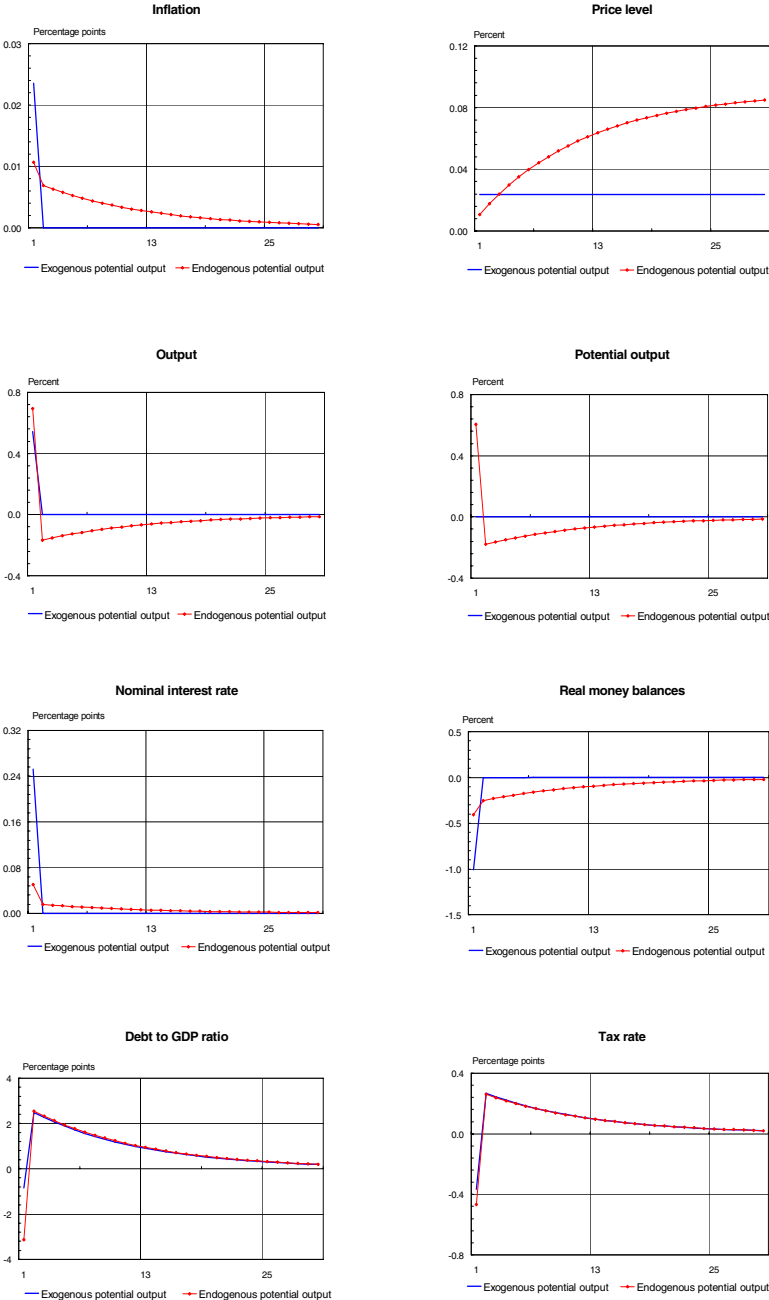


Figure 8: Temporary (one period) 1% increase in technology, deviations from baseline

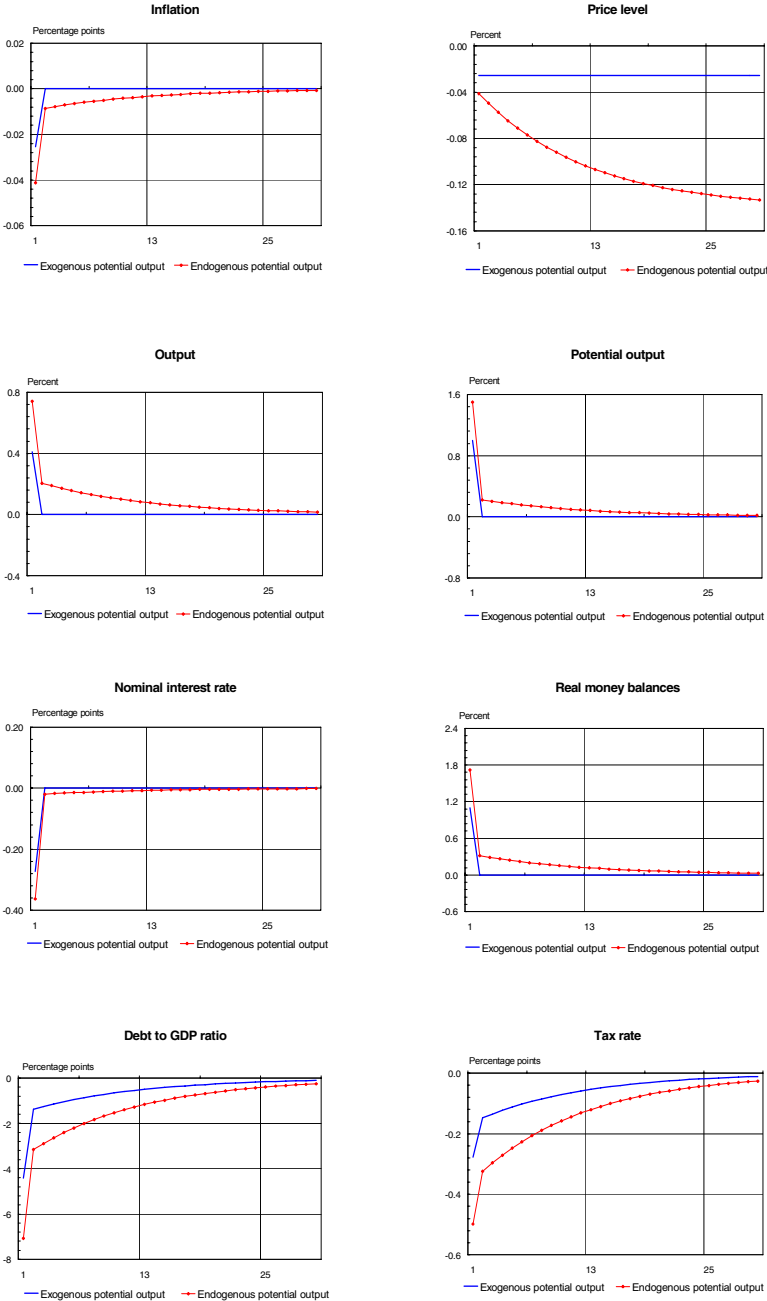


Figure 9: Temporary (one period) 1 percentage point increase in inflation target, deviations from baseline

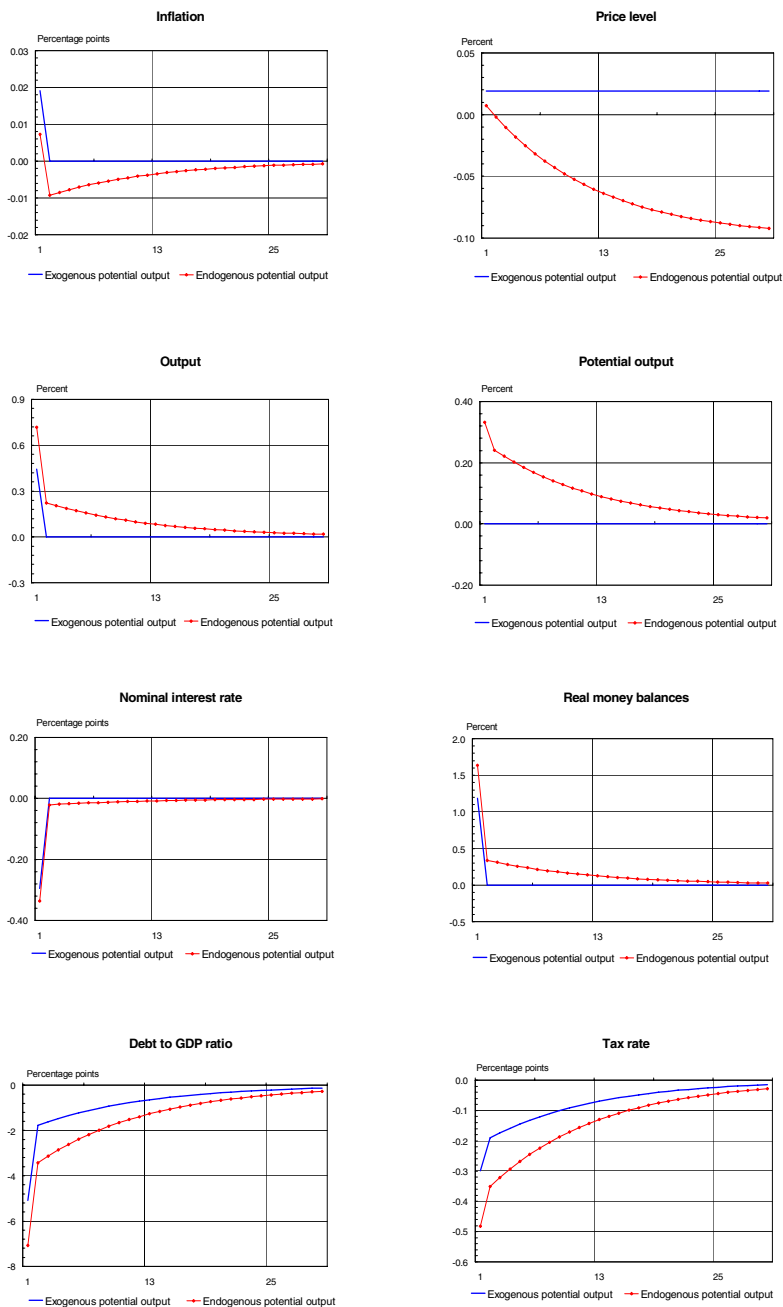


Figure 10: Temporary (one period) increase of 1% of real GDP in government consumption, deviations from baseline

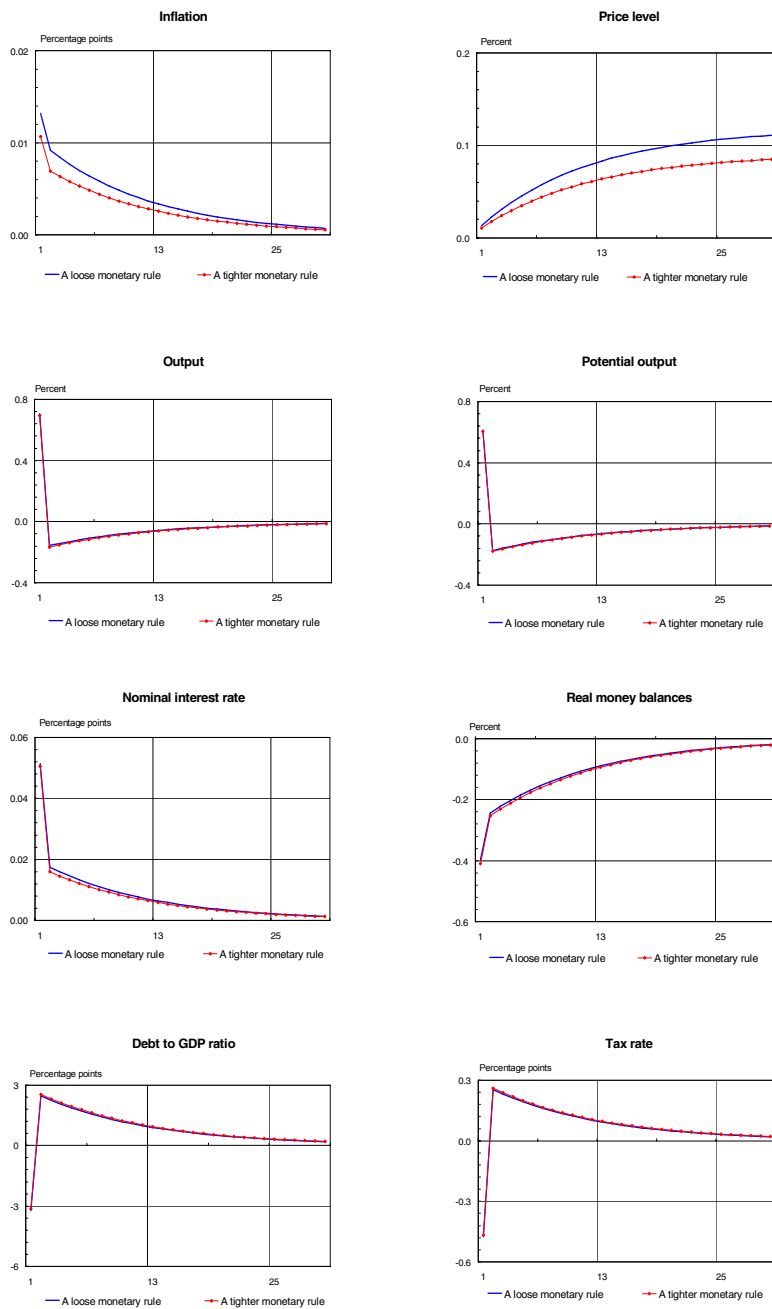
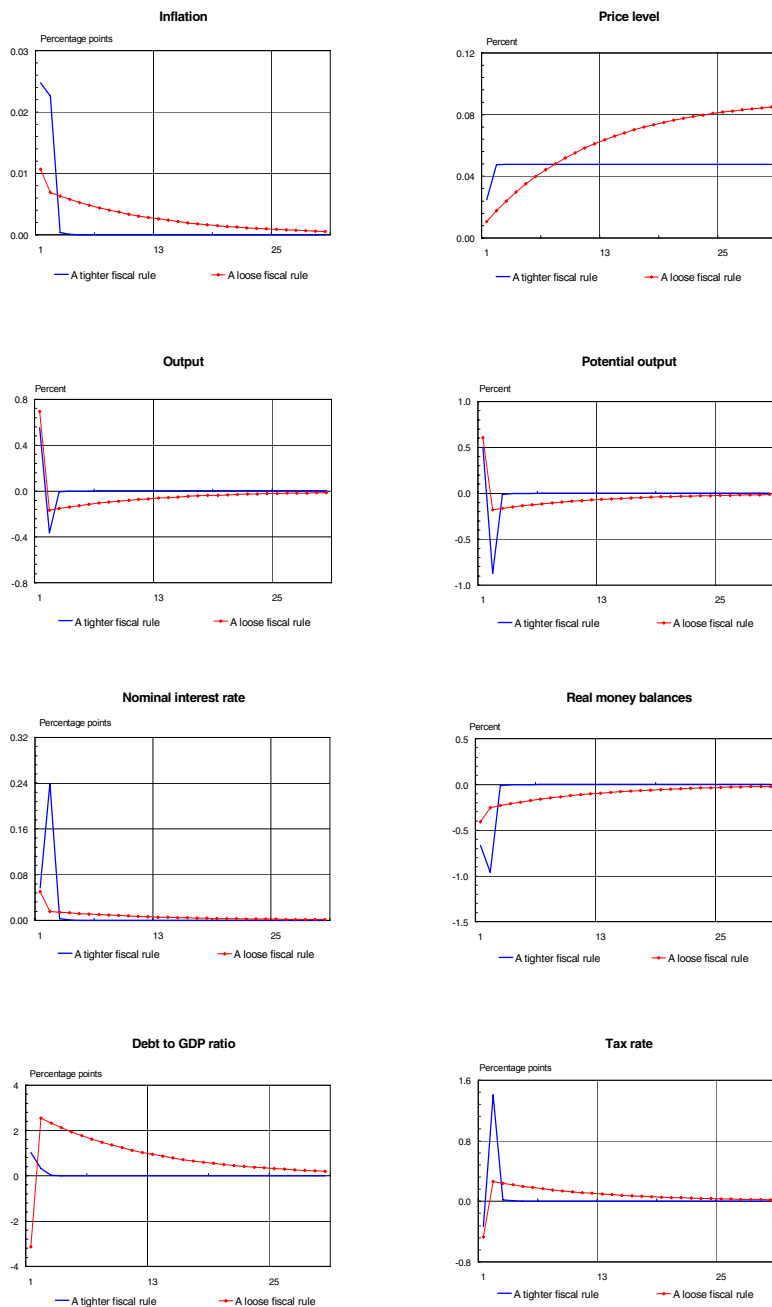


Figure 11: Temporary (one period) increase of 1% of real GDP in government consumption, deviations from baseline



Chapter 3

Stability consequences of fiscal policy rules

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Abstract

Using an optimised model with endogenous labour supply and a distortionary tax, rate we compare stabilising properties of different fiscal policy rules. The economy is affected by shocks from both government spending and technology. The fiscal policy rule can be based on government liabilities or government budget deficit. As both are given as measures of fiscal policy performance in the Stability and Growth Pact (SGP), we also use a fiscal policy rule based on a combination of the two. We compare the accounting definition of deficit with the economic definition, which takes inflation into account. The fiscal policy rule based on the debt, with monetary policy consistent with the Taylor principle, results in indeterminacy. However, a fiscal policy rule based on the deficit produces determinate solutions for a wide range of fiscal policy parameters. Moreover, we find that putting more weight on deficit than debt in the fiscal policy rule results in more moderate cyclical responses to shocks. Finally, we find that the SGP definition of deficit performs as well as the real deficit based on the government budget constraint.

1 Introduction

The link between monetary and fiscal policy has become increasingly important in the literature of monetary economics and public finance economics.¹ The discussion was revived by Sargent and Wallace's (1981) unpleasant monetary arithmetic. They stated that monetary policy is not able to control the evolution of the price level by itself and needs to be supported by fiscal policy. Also, the debate on the Stability and Growth Pact (SGP) in Europe is one example of just how seriously the relationship between these two areas should be taken.

Maintaining price stability requires commitment not only to an appropriate monetary policy rule but to an appropriate fiscal policy rule as well (Woodford, 2001). Fiscal policy rules can be based on government liabilities, as in Leeper (1991). Woodford (2001) concludes that a fiscal policy rule based on the government budget deficit combined with the Taylor (1993) rule for monetary policy results in a more attractive monetary-fiscal policy regime than the fiscal policy rule based on the debt. In this chapter we argue that particular monetary and fiscal policy regimes are consistent with stability of the economy while others are not.

In Leeper (1991) monetary and fiscal policy cannot both be active or passive at the same time if a determinate equilibrium is to exist. The basic finding is that, if the government budget constraint is fulfilled, an active monetary policy, ie a policy that raises the nominal interest rate by more than inflation increases, can stabilise the economy and ensure the uniqueness of equilibrium. At the same time a passive monetary policy, ie a policy that underreacts to inflation by raising the nominal interest rate less than the increase in inflation destabilises the economy. The dichotomy is also supported in the literature, eg by Evans and Honkapohja (2002a), who distinguish between polar cases by assuming that fiscal policy is either active or passive *ex ante*. Leith and Wren-Lewis (2000 and 2002) claim that dropping the assumption about fiscal policy regime renders *a priori* an determination as to active or passive fiscal policy regime. What are the options for fiscal policy to fulfil the government budget constraint, and how can fiscal policy be judged to be active or passive?

¹See eg Chari and Kehoe (1999), Woodford (1994, 1995, 1996, 2001), Sims (1994) and Benhabib, Schmitt-Grohé and Uribe (2001).

Both the debt and the deficit are given as measures of fiscal policy performance in the Maastricht treaty, and in this chapter we formulate a general fiscal policy rule based on combinations of the two. The definition of the budget deficit is based on the SGP definition (accounting definition). We also compare the accounting definition of the deficit to the real economic definition, which takes account of the effects of inflation. The fiscal rules relate change, not level, in tax rate to debt, deficit or both. This links the evolution of the tax rate to Barro's (1974, 1979) tax smoothing hypothesis.

Using the fiscal policy rule based on debt results in a non-determinate solution when monetary policy is consistent with the Taylor principle, ie with active monetary policy. However, the fiscal policy rule based on the SGP definition of the deficit produces determinate solutions with a wide range of fiscal policy parameters. Furthermore, we find that placing more weight on deficit than debt in the fiscal policy rule results in more moderate cyclical responses to shocks than if the weight on the debt is larger than on the deficit. Finally, we find that the SGP definition of deficit performs as well as the real deficit based on the government budget constraint, so that it is appropriate to use the SGP deficit in the fiscal policy rule.

We form a simple closed economy New Keynesian model with a public sector. Only proportional income taxes are available, and they have distortionary effects. We also derive endogenous potential output to respond not only to technology shocks but also to fiscal policy reactions, which defines the output gap appropriately. Price stickiness is introduced using Rotemberg's (1987) approach ie by assuming monopolistic competition in the goods market. Monetary policy follows a Taylor (1993) interest rate rule. In the economy, there are two different types of shocks, government spending and technology shocks, which are independent of each other.

The chapter is organised as follows. Section 2 runs through the optimisation problems for household and firm. In this section we also set out the government sector, excluding tax rules. In section 3 we formulate and represent the stability properties of deficit, debt, composite, and real deficit fiscal policy rules. We also show impulse responses to demand and supply shocks with different fiscal policy rules. Conclusions are drawn in section 4.

2 The model

2.1 The household

We begin by specifying an optimisation-based model with no capital. We use the money-in-the-utility function approach to model money in the general equilibrium model, as in Sidrauski (1967). A representative household seeks to maximise the expected lifetime utility function,²

$$E_t \sum_{t=0}^{\infty} \delta^t u(c_t, m_t, l_t), \quad (2.1)$$

subject to household's real budget constraint,

$$c_t + m_t - (1 - \pi_t)m_{t-1} + b_t \leq (1 + r_{t-1})b_{t-1} + (1 - \tau_t)(w_t l_t + \Pi_t), \quad (2.2)$$

where c_t is private consumption of the composite good, m_t real money balances, l_t households' labour supply, b_t government bonds held by the household, w_t the gross wage rate, Π_t firms' real profits and τ_t the income tax rate.³ The household's discount factor is δ and E_t is the expectation operator conditional on information available in period t . We assume that the utility function $u(c_t, m_t, l_t)$ is continuous, increasing and concave.

The first-order conditions are

$$u_c(c_t, m_t, l_t) - \xi_t = 0, \quad (2.3)$$

$$u_m(c_t, m_t, l_t) - \xi_t + \delta E_t [\xi_{t+1} (1 - \pi_{t+1})] = 0, \quad (2.4)$$

$$u_l(c_t, m_t, l_t) + \xi_t w_t (1 - \tau_t) = 0, \quad (2.5)$$

$$\xi_t = \delta E_t \xi_{t+1} (1 + r_t), \quad (2.6)$$

where ξ is the Lagrangean multiplier and subscripts indicate partial derivatives. Combining equations, the first-order conditions yield

$$\frac{u_c(c_t, m_t, l_t)}{E_t u_c(c_{t+1}, m_{t+1}, l_{t+1})} = (1 + r_t)\delta, \quad (2.7)$$

²The utility of the household depends on private and government consumption, which are assumed to be separable and not to affect the first-order conditions. Hence we overlook government consumption in the utility function. See Chapter 2.

³Inflation π is defined as $\frac{P_t - P_{t-1}}{P_t} = \pi_t$, which implies that $1 - \pi_t = \frac{P_{t-1}}{P_t}$. The real interest rate r_t is $1 + r_t = (1 + R_t)(1 - E_t \pi_{t+1})$, where R_t is the nominal interest rate and $E_t \pi_{t+1}$ the expected inflation rate.

$$u_m(c_t, m_t, l_t) = u_c(c_t, m_t, l_t) \frac{R_t}{1 + R_t}, \quad (2.8)$$

$$u_l(c_t, m_t, l_t) = -[u_c(c_t, m_t, l_t) w_t(1 - \tau_t)]. \quad (2.9)$$

Equation (2.7) is the Euler condition for optimal intertemporal allocation of consumption. Equation (2.8) states that the marginal rate of substitution between money and consumption is equal to the opportunity cost of holding money. The opportunity cost is directly related to the nominal interest rate. Equation (2.9) is the household's labour supply function, which states that the marginal rate of substitution between labour supply and consumption is equal to the real net wage rate.

Now we assume the periodic utility function to be $u(c_t, m_t, l_t) = \frac{c_t^{1-\sigma}}{1-\sigma} + \frac{\Gamma m_t^{1-\sigma}}{1-\sigma} - \frac{l_t^{1+\lambda}}{1+\lambda}$, where $\sigma \geq 0$ is the measure of risk aversion and Γ a positive constant. $\lambda \geq 0$ is the inverse of labour supply elasticity. The first-order conditions can be rewritten as

$$c_t^{-\sigma} = E_t c_{t+1}^{-\sigma} (1 + r_t) \delta, \quad (2.10)$$

$$\Gamma m_t^{-\sigma} = c_t^{-\sigma} \frac{R_t}{1 + R_t}, \quad (2.11)$$

$$-l_t^\lambda = -[c_t^{-\sigma} w_t(1 - \tau_t)]. \quad (2.12)$$

To log-linearise equations (2.10) and (2.11), we first take natural logarithms⁴ and rearrange to yield

$$\ln c_t = E_t \ln c_{t+1} - \frac{1}{\sigma} \ln(1 + r_t) - \frac{1}{\sigma} \ln \delta, \quad (2.13)$$

$$\ln m_t = \ln c_t - \frac{1}{\sigma} \ln \left(1 + \frac{1}{1 + R_t} \right) + \frac{1}{\sigma} \ln \Gamma. \quad (2.14)$$

Equation (2.13) holds in the steady state with values \bar{c}_t and \bar{r}_t , and equation (2.14) holds in the steady state with values \bar{m}_t , \bar{c}_t and $(1 + \bar{R}_t)$. We indicate steady state values of variables with bars and logarithmic fractional deviations from steady state values with hats. Subtracting steady state values and using definitions of logarithmic deviations from steady state (eg, for consumption, $\hat{c}_t = \ln \left(\frac{c_t}{\bar{c}_t} \right)$), we can rewrite equations (2.13) and (2.14) as

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma} \hat{r}_t, \quad (2.15)$$

⁴Note that $\frac{R_t}{1+R_t} = 1 - \frac{1}{1+R_t}$.

$$\widehat{m}_t = \widehat{c}_t - \frac{1}{\sigma} \widehat{R}_t. \quad (2.16)$$

The government purchases g_t of final output, which is in addition to household's consumption. To eliminate private consumption \widehat{c}_t from equations (2.15) and (2.16), we use the economy-wide resource constraint

$$y_t = c_t + g_t. \quad (2.17)$$

We follow the representation of Uhlig (1999) to obtain log-linear approximations. Log-linearisation of equation (2.17) around steady state yields

$$\widehat{y}_t = \frac{\bar{c}}{\bar{y}} \widehat{c}_t + \frac{\bar{g}}{\bar{y}} \widehat{g}_t. \quad (2.18)$$

Using the log-linearised resource constraint equation (2.18), we can write equations (2.15) and (2.16) as deviations from steady state:

$$\widehat{y}_t = E_t \widehat{y}_{t+1} + \frac{\bar{g}}{\bar{y}} [\widehat{g}_t - E_t \widehat{g}_{t+1}] - \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} \widehat{r}_t, \quad (2.19)$$

$$\widehat{m}_t = \frac{\bar{y}}{\bar{c}} \widehat{y}_t - \frac{\bar{g}}{\bar{c}} \widehat{g}_t - \frac{1}{\sigma} \widehat{R}_t. \quad (2.20)$$

We want to write equations (2.19) and (2.20) in (log) levels. We again use the definition of logarithmic deviation and the steady state versions of equations (2.13) and (2.14) to write

$$\ln y_t = E_t \ln y_{t+1} + \frac{\bar{g}}{\bar{y}} [\ln g_t - E_t \ln g_{t+1}] - \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} r_t - \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} \ln \delta, \quad (2.21)$$

$$\ln m_t = \frac{\bar{y}}{\bar{c}} \ln y_t - \frac{\bar{g}}{\bar{c}} \ln g_t - \frac{1}{\sigma} R_t + \frac{1}{\sigma} \ln \Gamma. \quad (2.22)$$

2.2 The firm

The representative profit maximising firm hires labour⁵ and produces and sells products in a monopolistically competitive goods market using the linear production technology

$$y_t = A l_t, \quad (2.23)$$

⁵We assume perfectly competitive labour markets and that there exists a continuum of identical firms. Hence there is no price dispersion.

where A describes technological development and is defined as $A = \zeta e^{\alpha * Time}$. Nominal profits are equal to

$$P_t \Pi_t = P_t y_t - P_t w_t l_t. \quad (2.24)$$

The representative firm faces the real marginal cost function

$$\frac{\partial}{\partial y_t} \left[w_t \left(\frac{y_t}{A} \right) \right] = w_t \frac{1}{A} \equiv mc_t. \quad (2.25)$$

Equilibrium wage rate is derived from labour supply, $l_t^S = c_t^{-\frac{\sigma}{\lambda}} w_t^{\frac{1}{\lambda}} (1 - \tau_t)^{\frac{1}{\lambda}}$, which depends on consumption and net wage, and labour demand, $l_t^D = \frac{y_t}{A}$, from the production function. Substituting equilibrium wage rate $w_t = c_t^{\sigma} \left(\frac{y_t}{A} \right)^{\lambda} (1 - \tau_t)^{-1}$ into the marginal cost equation and taking natural logarithms yields

$$\lambda \ln y_t - (1 + \lambda) \ln A + \sigma \ln c_t - \ln(1 - \tau_t) = \ln mc_t, \quad (2.26)$$

where $\ln A = \ln \zeta + \alpha * Time$. Denote $\ln \zeta \equiv z_t$ and assume that the productivity z_t follows the stochastic process

$$z_t = \rho z_{t-1} + \nu_t \quad (2.27)$$

with $0 \leq \rho \leq 1$ and that the white noise supply shock ν_t is *i.i.d.* $(0, \sigma_{\nu}^2)$. Equation (2.26) holds also in the steady state, so that percentage deviation of the marginal cost is given by

$$\lambda \hat{y}_t - (1 + \lambda) \hat{z}_t + \sigma \hat{c}_t - (1 - \hat{\tau}_t) = \hat{m}c_t. \quad (2.28)$$

Substitute the log-linearised resource constraint $\hat{c}_t = \frac{\bar{y}}{\bar{c}} \hat{y}_t - \frac{\bar{g}}{\bar{c}} \hat{g}_t$ into equation (2.28) to obtain

$$\left(\sigma \frac{\bar{y}}{\bar{c}} + \lambda \right) \hat{y}_t - \sigma \frac{\bar{g}}{\bar{c}} \hat{g}_t - (1 - \hat{\tau}_t) - (1 + \lambda) \hat{z}_t = \hat{m}c_t. \quad (2.29)$$

A monopolistically competitive firm sets its price as a mark-up over marginal cost. In the long-run equilibrium, the real marginal cost is equal to the inverse of the mark-up. Consequently, from equation (2.26) and the resource constraint, the (long-run) supply function is given by⁶

$$\ln y_t^* = \frac{\sigma \frac{\bar{y}}{\bar{c}}}{\sigma \frac{\bar{y}}{\bar{c}} + \lambda} \ln g_t + \frac{1 + \lambda}{\sigma \frac{\bar{y}}{\bar{c}} + \lambda} \alpha * Time + \frac{1}{\sigma \frac{\bar{y}}{\bar{c}} + \lambda} \ln(1 - \tau_t) + \varepsilon_t^y, \quad (2.30)$$

⁶In equilibrium, nominal price is equal to mark-up times nominal marginal cost. In real terms, $mc = \ln \frac{1}{\mu}$, where μ is the mark-up. See Chapter 2 for a more detailed derivation of equation (2.30).

where y_t^* is flexible price output, which we call potential output. Note that $\varepsilon_t^{y^*} \equiv [(1 + \lambda) / (\sigma \frac{\bar{y}}{c} + \lambda)] z_t$. Now the level of the economy's potential output is affected by fiscal variables, government consumption and taxation, along with technology. An increase in government consumption will expand the production possibilities. A decrease in taxation will increase potential output, since the household is willing supply more labour. Potential output equation (2.30) also holds in the steady state.

To find the firm's pricing equation, we follow Rotemberg (1987) and assume that it is costly to the firm to change prices. This assumption introduces price stickiness and reflects the empirical aspect that individual price setting is lumpy. The forward-looking firm sets prices by minimising the quadratic loss function

$$\frac{1}{2} E_t \sum_{j=0}^{\infty} \beta^j \left[(\ln P_{t+j} - \ln P_{t+j-1})^2 + a (\ln P_{t+j} - \ln P_{t+j}^*)^2 \right], \quad (2.31)$$

where $\beta = \frac{1}{(1+r)}$, $r > 0$ is the discount factor and a an adjustment cost parameter. The lower the value of a , the more costly it is to the firm to change prices. Taking the first-order conditions of equation (2.31) and replacing $(\ln P_t^* - \ln P_t)$ marginal cost, we can write the Phillips curve in terms of deviations from steady state

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + a \left[\left(\sigma \frac{\bar{y}}{c} + \lambda \right) \hat{y}_t - \sigma \frac{\bar{g}}{c} \hat{g}_t - (1 - \hat{\tau}_t) - (1 + \lambda) \hat{z}_t \right]. \quad (2.32)$$

Rewriting equation (2.32) using the notation $\hat{y}_t = \ln \frac{y_t}{\bar{y}_t}$ and equation (2.30), we obtain the expectations, technology and tax augmented Phillips curve as

$$\pi_t = \beta E_t \pi_{t+1} + a \left[\left(\sigma \frac{\bar{y}}{c} + \lambda \right) (\ln y_t - \ln y_t^*) \right]. \quad (2.33)$$

Current inflation depends on expected future values of inflation, not on past inflation. The model resembles that in Woodford (1999), where he points out that there is an important dynamic link from expectations to the present, for both inflation and output. Leong (2002) finds support for the forward looking New Keynesian model from simulation exercises. Unlike Woodford (1999), we treat potential output y_t^* endogenously instead of as an exogenous disturbance.

2.3 The government

We construct the intertemporal budget constraint for the policy authority, which links debt and policy choices. The consolidated real flow budget constraint of the government sector is

$$b_t + \tau_t y_t + \pi_t m_{t-1} + m_t - m_{t-1} = (1 + r_{t-1}) b_{t-1} + g_t, \quad (2.34)$$

where b_t is government bonds, $\tau_t y_t$ tax revenue, m_t nominal money balances, r_t the real interest rate and g_t government consumption. The government balances its budget with new debt, taxes and seigniorage revenue ($\pi_t m_{t-1} + m_t - m_{t-1}$). The government taxes the income, $y_t = w_t l_t + \Pi_t$, and τ_t is the income tax rate. The intertemporal government budget constraint is

$$(1 + r) b_t \leq \sum \left(\frac{1}{1 + r_{t+i}} \right)^i (\pi_{t+i} m_{t-1+i} - m_{t-1+i} + m_{t+i} + \tau_{t+i} y_{t+i} - g_{t+i}), \quad (2.35)$$

which says that the maximum level of outstanding debt, including interest payments, is determined by the sum of discounted seigniorage revenues and surpluses. Fiscal policy can rely on seigniorage funding to some extent. Schmitt-Grohé and Uribe (2002) show that even a small amount of price stickiness is sufficient to constrain the inflation tax, so that the government will rely more on conventional taxes.

Government expenditure is characterised by a ratio to output, to ensure convergence of the solution, since we have non-stationary government consumption and output paths. This simultaneous link between government consumption and output may amplify some the results, but is necessary for the constant steady state ratio between government consumption and output. The autoregressive process for government consumption is

$$\frac{g_t}{y_t} = \rho^g \frac{g_{t-1}}{y_{t-1}} + (1 - \rho^g) \bar{\gamma} + \varepsilon_t^g, \quad (2.36)$$

where $\bar{\gamma}$ is the constant government consumption-to-GDP ratio, $0 \leq \rho^g \leq 1$, and ε_t^g is *i.i.d.* $(0, \sigma_{\varepsilon^g}^2)$. We assume that the two shocks hitting the economy, technology and government spending shocks, are independent of each other. Hence we need not specify their covariance.

We assume that the interest rate is set according to the Taylor (1993) rule. The interest rate setting is based on domestic economic conditions, with a positive weights on inflation and real output. Taylor suggested that the increase in the nominal interest rate should be more than one-for-one in response to inflation. We write the interest rate rule with respect to inflation deviations from inflation target and output deviation from potential output

$$R_t = \pi_t + r^* + \eta_1 (\pi_t - \pi^*) + \eta_2 (\ln y_t - \ln y_t^*), \quad (2.37)$$

where r^* is the real interest rate in steady state, π^* the inflation target, and y_t^* potential output at time t , defined by equation (2.30). The rule represents interaction between monetary and fiscal policy, since y_t^* is affected by fiscal policy variables. The Taylor principle requires $\eta_1 > 0$ and $\eta_2 > 0$. The larger the values of η_1 , the tighter the monetary policy. In the literature, the discussion of the form of interest rate rule has emphasised the simple, robust rule and stabilisation properties. We use the contemporaneous-time interest rate rule, which according to Bullard and Mitra (2002) is determinate for a wider range of parameter values than is the forward looking rule. However, we check the stability of the model for a wide range of monetary policy rule parameter values, since Edge and Rudd (2002) argued that distortionary taxation increases the value of the Taylor rule parameter that is consistent with stability of the economy. To complete the model, we formulate fiscal policy using tax rules based on deficit, debt and combinations of the two.

3 Stabilising properties of the model

3.1 Parameters

In the calibration exercise parameter values are set for the stability analysis and model simulation at levels that are in line with the literature⁷. The risk aversion coefficient σ is set at 0.5 and the interest rate coefficient of the IS curve at $\frac{\bar{c}_t}{\bar{y}_t} \frac{1}{\sigma} = 1.5$. Setting $\lambda = 1.5$, the labour supply elasticity with respect to real wages becomes 0.67. With the adjustment cost parameter a set at 0.02, the output coefficient in the Phillips curve is $a \left(\sigma \frac{\bar{y}_t}{\bar{c}_t} + \lambda \right) = 0.043$. The ratio of government consumption to output is set at 0.25, so that $\frac{\bar{c}_t}{\bar{y}_t} = 0.75$ and $\frac{\bar{y}_t}{\bar{c}_t} = 1.34$. The output coefficient in the Taylor rule η_2 is set at 0.4, which is smaller than in the original Taylor (1993) rule and indicates that monetary authority is less concerned with output than suggested by Taylor. The inflation target $\pi^* = 0.02$ and the long term real interest rate r^* is 0.03.

The household discount factor δ is 0.98, but the firm's discount rate β is set at one. The income elasticity of money demand is 1.34 and the interest rate elasticity of money is 2. The ratio of money balances to GDP is 0.12 as the coefficient Γ is set at 0.3. The share of government consumption of GDP is 25% and so $\bar{\gamma} = 0.25$. The Maastricht Treaty defines the deficit and debt requirements. Accordingly the deficit-to-GDP ratio is $\psi_1 = 0.03$ and real debt-to-GDP target $\psi_2 = 0.6$.

We calibrate persistence of the technology shock hitting the economy using Cooley and Prescott (1995), who find that 95% of a shock remains after one quarter. Thus in annual terms we set $\rho = 0.81$. Blanchard and Perotti (2002) estimated that 95% of a government consumption shock is still present after two years. Following them, we set $\rho^g = 0.975$. The parameter values reflect the economic structure of a large economy such as the euro area.

⁷On calibration, see eg Rotemberg and Woodford (1999), Clarida, Galí and Gertler (2000) and Bullard and Mitra (2002).

3.2 Deficit rule

Recent monetary policy literature has emphasised the links between degrees to which monetary and fiscal policies respond to inflation, debts, deficits and macroeconomic stability. Leeper (1991) studied a fiscal policy rule based on government liabilities. The fiscal policy rule based on debt is widely used in the literature. Evans and Honkapohja (2002a) used a debt-based fiscal policy rule to study learnability conditions for fiscal and monetary policy. The real debt is used in the fiscal policy rule and, as mentioned in Woodford (2001), monetary policy affects the real value of outstanding debt through its effects on the price level. Hence monetary policy has effects on the real debt and links monetary policy to fiscal policy.

Woodford (2001) finds an analogue between fiscal policy rules based on government liabilities and the government budget deficit. He concluded that fiscal policy based on the government budget deficit is a more attractive monetary-fiscal policy regime (with the Taylor rule monetary policy) than is fiscal policy based on government liabilities. He also finds that the fiscal policy rule based on both debt and deficit results in a determinate solution for the price level.

Below, we study four different fiscal policy rules. First we use the government deficit tax rule, as recommended by Woodford (2001), with Taylor rule monetary policy. The government budget deficit used is the accounting definition of the Maastricht treaty and Stability and Growth Pact (SGP). Second, we use a rule with real government liabilities, as in Leeper (1991). Third, we formulate a fiscal policy rule using both deficit and debt. This imitates SGP measures of fiscal policy performance, which enables us to study how much weight should be put on each of the two. Finally, we use the real definition of deficit derived from the government budget constraint and compare it with the SGP definition of deficit, which we explore first.

First, the fiscal authority reacts according to the rule based on the accounting definition of the government budget deficit. The government budget deficit is defined as the difference between tax revenue, $\tau_t y_t$, government spending, g_t , and interest payments on real debt, $R_t b_{t-1}$.⁸ This is the accounting definition that we use to imitate

⁸We use the nominal interest rate to approximate the interest payments on real government debt instead of the correct $R_t - \pi_t R_t$. With low inflation and nominal interest rates the latter term is quite small.

the SGP way of calculating the deficit. The fiscal policy rule with SGP deficit can be written as

$$\tau_t = \tau_{t-1} + \Omega [g_t - \tau_t y_t + R_t b_{t-1} - \psi_1 y_t] / y_t, \quad (3.1)$$

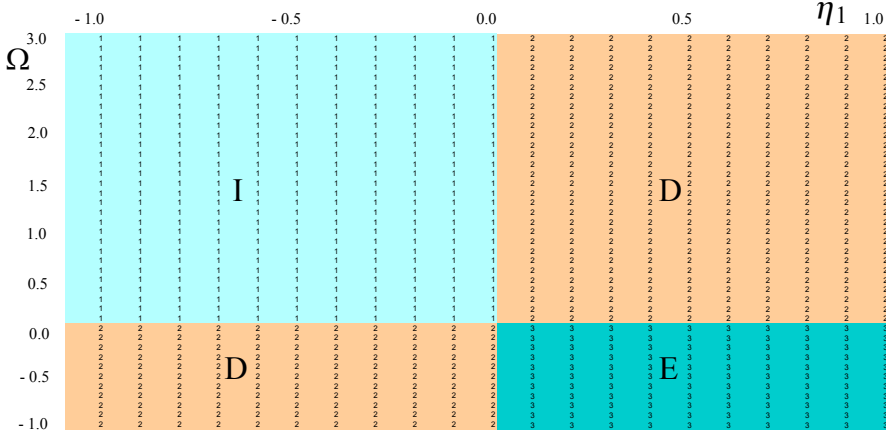
where parameter $\psi_1 \geq 0$ can be interpreted as a constant target level for the deficit-to-GDP ratio, as in Woodford (2001). If $\psi_1 = 0$, we have a special case of the balanced budget rule for the long run. Woodford (2001) concludes that adoption of the deficit target in conjunction with the Taylor rule for monetary policy would create a regime consistent with low inflation. Note that the rule (3.1) relates the change (not level) in tax rate to the deviation of deficit from target. We chose the contemporaneous deficit for computational reasons. Writing the deficit rule with previous-period deficit would make it more like the debt rule which depends on previous-period government liabilities. Moreover simultaneity with endogenous variables would have been avoided. However, the previous-period deficit includes the real debt with two lags, in which case the dimension of matrix M below would increase and the stability analysis would become more difficult. On the other hand, the timing of the primary deficit $g_t - \tau_t y_t$ in the deficit rule (3.1) is similar to that in the real deficit rule (3.14) derived from the government budget constraint.

In order to find fiscal policy parameter values consistent with low inflation, we analyse the stability of the model using the methods of Blanchard and Kahn (1980). When the model is written in state-space form, the Blanchard-Kahn requirement for a unique solution under rational expectations is that the number of roots inside the unit circle must equal the number of non-predetermined variables .

The system is given by the output equation (2.19), real money balances equation (2.20), potential output equation (2.30), government consumption (2.36), inflation equation (2.33), government budget constraint equation (2.34), interest rate rule equation (2.37), and tax rule equation (3.1). It has 2 non-predetermined variables, output and inflation ($\hat{y}, \hat{\pi}$). Defining

$$\begin{aligned} \hat{X}'_t &= \begin{bmatrix} \hat{y}_t & \hat{\pi}_t \end{bmatrix}, \\ \hat{x}'_t &= \begin{bmatrix} \hat{g}_t & \hat{b}_t & \hat{\tau}_t \end{bmatrix}, \\ \epsilon &= \begin{bmatrix} \epsilon_t^{y^*} & \epsilon_t^g \end{bmatrix}, \end{aligned} \quad (3.2)$$

Figure 1: Determinate, indeterminate and explosive zones with the deficit rule



where \widehat{X}'_t is the vector of non-predetermined variables, \widehat{x}'_t the vector of predetermined variables, and ϵ the vector of shock variables, we write the reduced form as

$$A \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = B \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + C\epsilon, \quad (3.3)$$

or

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = M \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + N\epsilon, \quad (3.4)$$

where $M = A^{-1}B$. Matrix M is defined with suitable matrices A and B defined in Appendix A, and matrix $N = A^{-1}C$ is omitted. Matrix M is a 5×5 matrix with 5 roots. For determinacy, we require the number of roots of matrix M inside unit circle to be two.

Figure 1 shows the number of roots of matrix M inside the unit circle when the Taylor rule parameter η_1 for inflation runs from -1 to 1 and the deficit rule parameter Ω runs from -1 to 3. Zones D, E and I are associated with parameter values of η_1 and Ω for which the solutions are determinate, indeterminate or explosive.

We define an active fiscal policy as one that it is not constrained by budgetary conditions, whereas a passive fiscal policy must generate sufficient tax revenues to balance the budget. Sargent (1982) refined Barro's (1974) idea about Ricardian equivalence applied to the public debt so that in a Ricardian (passive) fiscal policy regime fiscal policy

must ensure that the government's intertemporal budget constraint is always in balance. The passive decision rule depends on government debt, summarised by current and past variables, while the active rule can be formed more freely from past, current or expected future variables. Fiscal policy becomes more passive when the value of the fiscal policy rule parameter that relates taxes to debt or deficit increases.

Introduction of distortionary taxation and the supply-side channel for fiscal policy links monetary and fiscal policy parameters in the stability analysis such that it is impossible to dominant policy a priori, as shown in Chapter 2. Leith and Wren-Lewis (2000 and 2002) find that excluding the assumption of an active fiscal policy regime means that distinguishing in advance between monetary policy- or fiscal policy-dominated regimes is difficult.

In Figure 1, the determinate regions for the model are on the upper right hand side and lower left hand side. On the right hand side there is a unique solution with the Taylor rule parameter η_1 larger than zero, which is Taylor's (1993) requirement that the interest rate react more than one-for-one to inflation, with the fiscal rule parameter Ω greater than zero.

In the right hand side determinate zone, monetary policy is always active, but the degree of nominal interest rate response varies. The magnitudes of impacts on real interest rate, output and price level depend on the magnitude of nominal interest rate response. However, fiscal policy can change from active to passive, ie the value of Ω can increase. Fiscal policy does affect inflation and the real interest rate to the extent that it is consistent with monetary policy. Hence monetary and fiscal policy together determine the price level.

We claim that fiscal policy can be active together with an active monetary policy and still be consistent with dynamic stability of the economy. This contradicts findings in Leeper (1991) and Evans and Honkapohja (2002a), who claim that fiscal policy cannot be active together with active monetary policy and result in determinate solutions. Hence we conclude that the distortionary tax rate, together with the supply side channel, changes the dichotomous interpretation and enables an active monetary-fiscal policy regime with fiscal policy rule based on government deficit.

The other determinate zone is where the Taylor principle is no longer valid. In the lower left hand corner, the fiscal policy parameter gets negative values. Here, monetary policy is not able to stabilise

the economy, so that fiscal policy affects inflation, real interest rate, and price level so as to ensure stability of the economy.

In the upper left hand corner, with a negative Taylor rule parameter and the positive fiscal parameter, there is indeterminacy and no unique solution. The lower right hand corner displays parameter values the zone with explosive solutions. In this zone neither monetary nor fiscal policy can determine the price level.

Some previous studies have gotten interesting results on the time profile of tax rates. Niepelt (2002) finds that, with distortionary taxes and a representative agent model, the optimal tax profile is flat reflecting the tax smoothing properties in Barro (1979). Chari, Christiano and Kehoe (1991) suggest that, as an outcome of optimal fiscal policy, the tax rate is roughly constant instead of exactly flat. Chari, Christiano and Kehoe (1994) state that a labour tax inherits the persistence properties of the exogenous shock.

Figure 2 shows responses to a government spending shock with different fiscal policy parameter values. The government spending shock is a one-off 1%-of-GDP increase in government consumption. The shock is fairly persistent: 95% remains after two years. The solid line represents the case where $\Omega = 0.01$, which is active fiscal policy and with taxes virtually unchanged initially. The dotted line is also for active, but more loose, fiscal policy with $\Omega = 0.1$ and the triangle line represents passive fiscal policy with $\Omega = 1$. The greater the weight on the deficit in the fiscal policy rule, the more important it is for the fiscal authority to keep the budget balanced. The monetary policy parameter is set at 0.5, which is a common value for the Taylor rule parameter.

In the short run, the output response depends on the fiscal policy parameter. With low values of Ω , output increases by about 0.3% initially, but high values result in a decrease in output, even in the short run. In the long run, the resource constraint generates a reduction of output due to crowding out of private consumption. With high values of Ω , the debt-to-GDP ratio is fairly constant and the tax rate reflects the pattern of the shock more closely than with low values of Ω . The higher the value of the fiscal policy parameter, the more the tax rate changes initially, which results in larger responses of inflation and nominal interest rate initially, as the output gap tends to be positive. Low values of Ω put the economy through debt adjustment and we see that the initial debt financing of government consumption will be paid by a future increase in the tax rate. Passive fiscal policy with large changes in taxation causes

more inflation and less output in the short run than does active fiscal policy.

Figure 3 shows the response to a 1% technology shock. The technology shock is also one-off, but less persistent than the government spending shock. Of the technology shock, 95% remains after one quarter. Again the solid line represents the case with $\Omega = 0.01$, for the dotted line $\Omega = 0.1$, and the triangle line shows responses with $\Omega = 1$. The technology shock has positive output and inflation effects. Changes in fiscal policy parameter values have negligible impacts on output, inflation and interest rates. The technology shock increases output initially by more than 1% due to labour supply effects. As a result of the technology shock, the tax rate drops initially and labour supply increases. Potential output increases even more, due to the improvement in technology. The resulting negative output gap lowers inflation and the interest rate. The debt-to-GDP ratio decreases initially as output increases. Passive fiscal policy with large values of Ω aims at keeping debt unchanged and taxes fall the most in the short run. As a result, the debt-to-GDP ratio returns to baseline values fastest.

3.3 Debt rule

An alternative to the deficit rule is to tie taxes to government liabilities. Leeper (1991) based his simple rule on debt, where the policy parameter is directly incorporated into the real government debt. In his model taxes were lump-sum and fluctuated around a constant. Total government liabilities are $b_{t-1} + m_{t-1}$, and the debt rule is written as

$$\tau_t = \tau_{t-1} + \phi [(b_{t-1} + m_{t-1}) - \psi_2 y_t] / y_t, \quad (3.5)$$

where $\psi_2 > 0$ can be interpreted as the target level for the real government debt-to-GDP ratio, as in Woodford (2001).

The system is identical to that in the previous section, but the deficit rule is replaced by the debt rule equation (3.5). We define

$$\begin{aligned} \widehat{X}'_t &= \begin{bmatrix} \widehat{y}_t & \widehat{\pi}_t \end{bmatrix}, \\ \widehat{x}'_t &= \begin{bmatrix} \widehat{g}_t & \widehat{b}_t & \widehat{\tau}_t \end{bmatrix}, \\ \epsilon &= \begin{bmatrix} \epsilon_t^{y^*} & \epsilon_t^g \end{bmatrix}, \end{aligned} \quad (3.6)$$

Figure 2: Government consumption shock with deficit rule, deviations from baseline

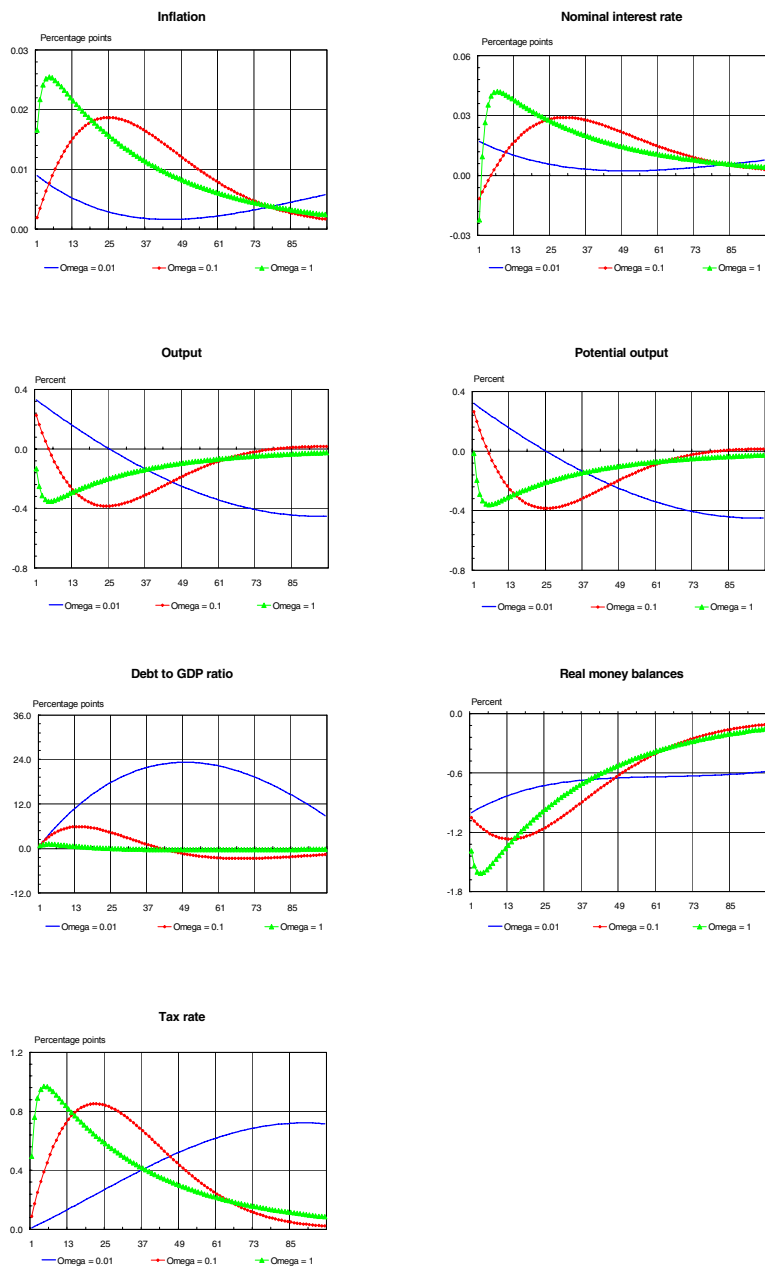


Figure 3: Technology shock with deficit rule, deviations from baseline

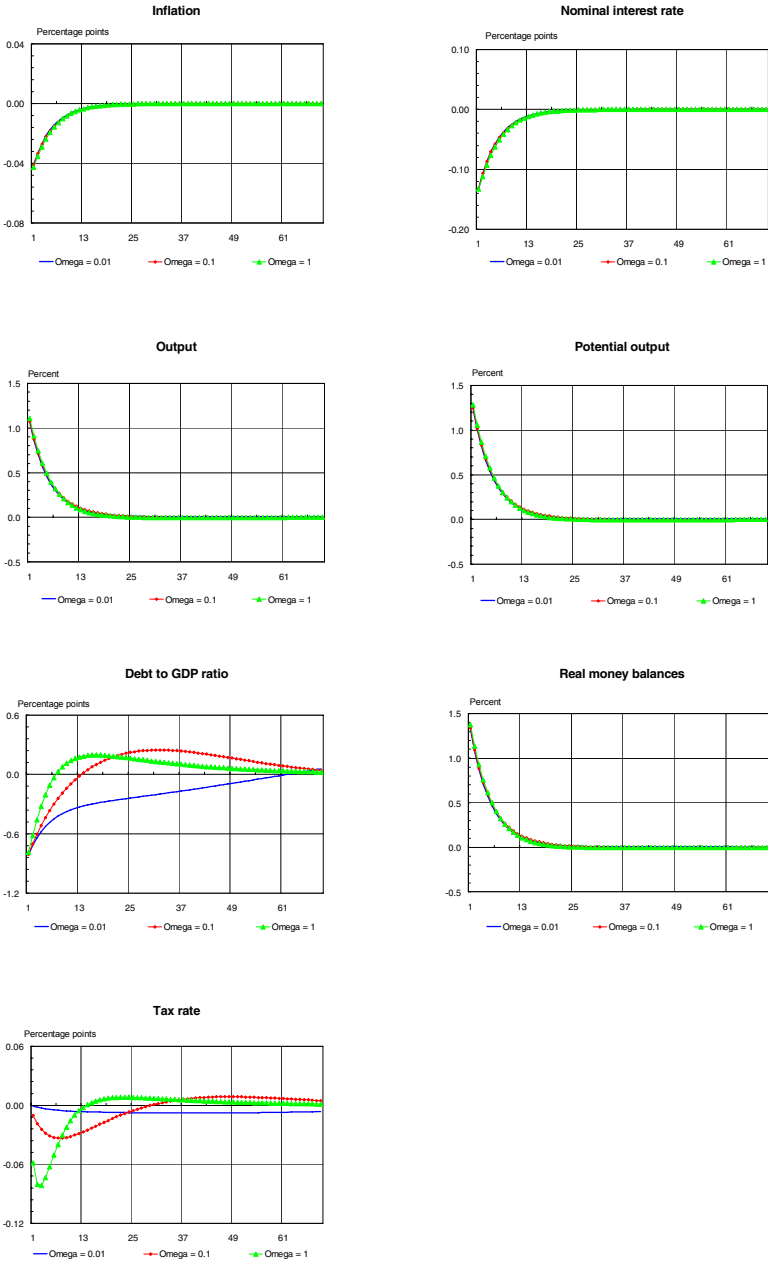
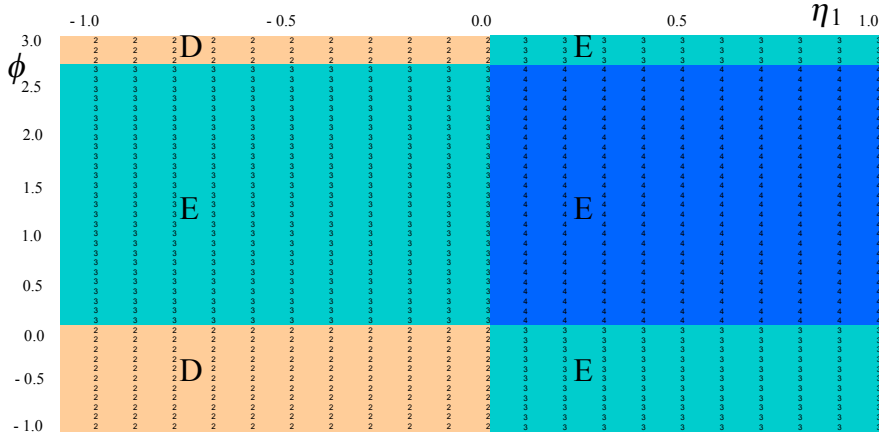


Figure 4: Determinate, indeterminate and explosive zones with the debt rule



where \widehat{X}'_t is the vector of non-predetermined variables and \widehat{x}'_t is the vector of predetermined variables. We write the reduced form as

$$A \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = B \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + C\epsilon, \quad (3.7)$$

or

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = M \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + N\epsilon, \quad (3.8)$$

where $M = A^{-1}B$. Matrix M is defined by suitable matrices A and B defined in Appendix B.

Figure 4 corresponds to Figure 1 in the case of the debt rule. In this figure, the Taylor rule parameter η_1 for inflation runs from -1 to 1 and the debt rule parameter ϕ runs from -1 to 3.

In Figure 4 the determinate zones are in the upper and the lower left hand corners. The economy is always explosive with active monetary policy, regardless of value of the fiscal policy parameter ϕ . In Chapter 2 the debt rule was found to be consistent with dynamical stability of the economy with a monetary policy consistent with the

Taylor principle.⁹ However, under the tax smoothing assumption, the debt rule turns out to result in indeterminacy with active monetary policy. Now the tax (fiscal policy) reaction affects the real interest rate strongly and hence the price level is no longer determinate.

Interestingly, the lower left hand corner represents exactly the same pattern of determinate solutions as in Chapter 2. The negative fiscal policy parameter values imply that an increase in debt results in a lower tax rate. Also in the upper left corner, there is a determinate zone if fiscal policy parameter is close to 3, which is extremely high since it means that for each 1 percentage point rise in debt-to-GDP the tax rate should increase by 3 percentage points. Because monetary policy is passive, fiscal policy can affect inflation and the real interest rate so as to ensure stability. The debt rule results in a determinate solution only if monetary policy does not fulfil the Taylor principle requirement, ie only if monetary policy is passive. We have defined that the high values of ϕ to mean passive fiscal policy. Hence there exists a determinate equilibrium with passive fiscal and passive monetary policy.

3.4 Composite rule

We also combine the previous rules. The composite fiscal policy rule follows the SGP requirements for fiscal stability. The change in the tax rate respond to the accounting budget deficit written in real terms and to the level of real debt outstanding. The composite fiscal policy rule is

$$\begin{aligned} \tau_t = & \tau_{t-1} + \{\Omega [(g_t - \tau_t y_t + R_t b_{t-1}) - \psi_1 y_t] \\ & + \phi [(b_{t-1} + m_{t-1}) - \psi_2 y_t]\} / y_t, \end{aligned} \quad (3.9)$$

where $\psi_1 \geq 0$ and $\psi_2 > 0$ are the deficit- and debt-to-GDP ratio targets respectively. The rule gives a systematic policy response to economic conditions. The fiscal authority responds to the debt in the magnitude ϕ and to the deficit in the magnitude Ω . The system

⁹In Chapter 2 we find that relative to the case of only demand side effects, introducing supply side effects of fiscal policy reduces the range of parameter values that result in determinate REE equilibria. The results were produced under the assumption that the tax rate evolves around a fixed tax rate, as in Leeper (1991), not under the random walk assumption of Barro (1979).

is identical to that in the previous section with the composite rule equation (3.9) instead of the debt rule. Using the definition

$$\begin{aligned}\widehat{X}'_t &= [\widehat{y}_t \quad \widehat{\pi}_t], \\ \widehat{x}'_t &= [\widehat{g}_t \quad \widehat{b}_t \quad \widehat{\tau}_t], \\ \epsilon &= [\epsilon_t^{y^*} \quad \epsilon_t^g],\end{aligned}\tag{3.10}$$

where \widehat{X}'_t is the vector of non-predetermined variables and \widehat{x}'_t the vector of predetermined variables, we can write the reduced form as

$$A \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = B \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + C\epsilon,\tag{3.11}$$

or

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = M \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + N\epsilon,\tag{3.12}$$

where $M = A^{-1}B$. Matrix M is defined by suitable matrices A and B defined in Appendix C.

In Figure 5 the parameter space is once again decomposed into determinate (D), indeterminate (I) and explosive (E) zones corresponding to RE solutions of the model. The deficit parameter Ω runs from -1 to 1 and the debt parameter ϕ runs from -1 to 2, while the Taylor rule parameter η_1 is held constant at 0.5, ie monetary policy is active.

We can see from Figure 5 that the economy has a unique REE for a wide range of positive values for debt and deficit when monetary policy is active. The same combination results in an explosive solution with passive monetary policy.

Figure 6 fixes the debt parameter in the composite fiscal policy rule at $\phi = 0.1$ and shows the structure of the set of model solutions when the Taylor rule parameter runs from -1 to 1 and the deficit parameter Ω runs from -1 to 3.

Figure 7 repeats Figure 6 but with the deficit parameter fixed at $\Omega = 0.1$ and the debt rule parameter ϕ running from -1 to 3. If the deficit parameter Ω is kept constant and low, the weight of the debt, ϕ can be set at a high value with active monetary policy and there will be a determinate equilibrium. In the opposite case, when the weight of debt in the fiscal policy rule is kept constant and low, the weight of the deficit is much more restricted to obtain determinate solution. On the right hand side of Figure 6 there is a determinate

Figure 5: Determinate, indeterminate and explosive zones with the composite rule when $\eta_1 = 0.5$

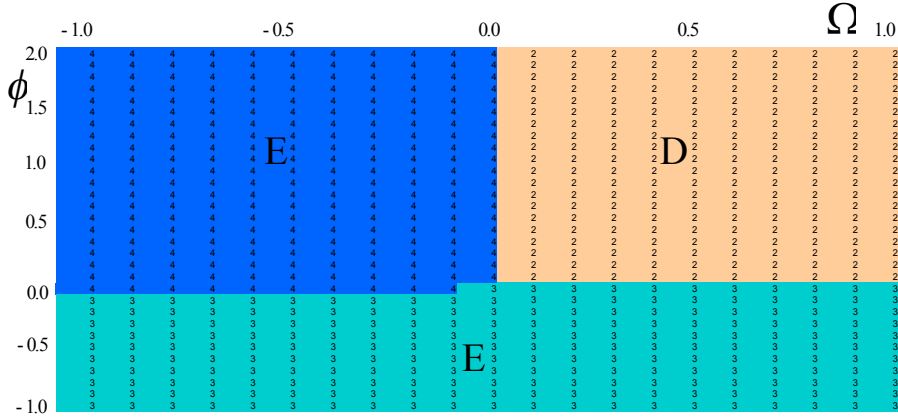


Figure 6: Determinate, indeterminate and explosive zones with the composite rule when $\phi = 0.1$

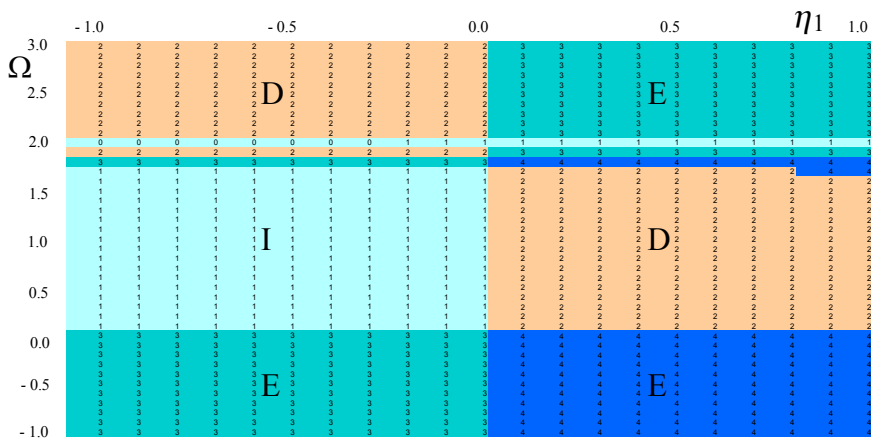
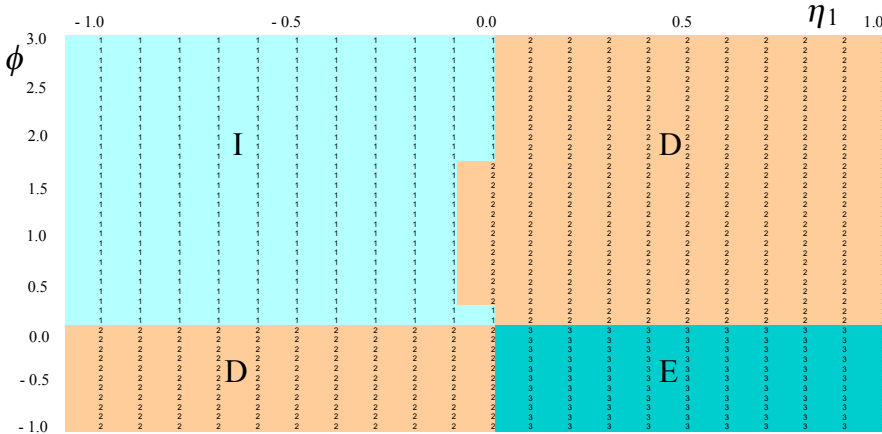


Figure 7: Determinate, indeterminate and explosive zones with the composite rule when $\Omega = 0.1$



equilibrium with active monetary policy and positive values of the rule weights. A high weight on the deficit combined with a low weight on debt destabilises the economy with active monetary policy, but actually stabilises it with passive monetary policy. The structure of the solutions is more complex with the composite rule than with the previous two rules, as seen from the striped pattern in Figure 6. The solution has more complex roots than the other cases explored in this chapter. It also implies cyclical impulse responses. Koskela and Puhakka (2003) studied the effect of distortionary taxation on cycles in a simple OG model. They found that there are levels of the tax rate that change the cyclical properties of the economy.

In Figure 8 we show the dynamic responses to the government spending shock with the composite fiscal policy rule. The shock is much as described above. The dotted line represents the case when there is more weight on deficit than debt ($\Omega = 0.5$ and $\phi = 0.1$). The triangle line is the opposite case with $\Omega = 0.1$ and $\phi = 0.5$. The responses to the shock illustrate the feature that, with more weight on debt than deficit, the economy is more likely to exhibit cycles. Cyclicity is reduced under the tax rule with more weight on deficit than debt. Because the total weight for deficit and debt is so high, an increase in government spending raises the tax rate initially so much that output actually declines also in the short run.

Figure 9 presents responses to a government spending shock. The solid line is the case with low weight on both deficit and debt ($\Omega = 0.01$ and $\phi = 0.01$). The dotted line has higher weights ($\Omega = 0.1$ and $\phi = 0.1$) and the triangle line represents the passive fiscal policy with weights ($\Omega = 1$ and $\phi = 1$). We see that reducing the weight on both deficit and debt makes the economy fluctuate with longer cycles. With low weights, the initial impact of a positive spending shock is positive for real values and negative for inflation. The response of the tax rate is small, but the debt-to-GDP ratio increases sharply. With higher weights, the debt-to-GDP ratio remains little changed, but the change in tax rate reduces output. Inflation increases as well. Responses to technology shocks show the same pattern. Putting more weight on both deficit and debt reduces fluctuation. The impulse response functions for a technology shock with the composite fiscal policy rule are presented in Figures 11 and 12.

3.5 Real deficit rule

Instead of using the SGP definition of deficit, we formulate the tax rule using the economic definition of deficit. The real deficit rule is derived from the government budget constraint. We rewrite the government real flow budget constraint as

$$b_t - b_{t-1} + m_t - m_{t-1} = g_t - \tau_t y_t + r_{t-1} b_{t-1} - \pi_t m_{t-1}, \quad (3.13)$$

where the right hand side defines the real deficit. Now the fiscal policy rule for real deficit can be written as

$$\tau_t = \tau_{t-1} + \Omega [(g_t - \tau_t y_t + r_{t-1} b_{t-1} - \pi_t m_{t-1}) - \psi_3 y_t] / y_t, \quad (3.14)$$

where $\psi_3 \geq 0$ is the target level for the real deficit-to-GDP ratio. Now, in addition to the primary deficit, increases in of the tax rate are affected by the real interest payments on debt and the real inflation tax on the money stock.

Figure 10 shows impulse responses to a government spending shock. The dotted line represents the deficit rule with $\Omega = 0.1$ and the triangle line shows the real deficit rule with the same policy parameter value. With the real deficit, the tax rate reacts slightly less and hence the debt-to-GDP ratio adjusts back to the baseline slower than with the accounting deficit definition. Therefore with the real deficit definition, inflation responses are slightly smaller and

Figure 8: Government consumption shock with composite rule, deviations from baseline

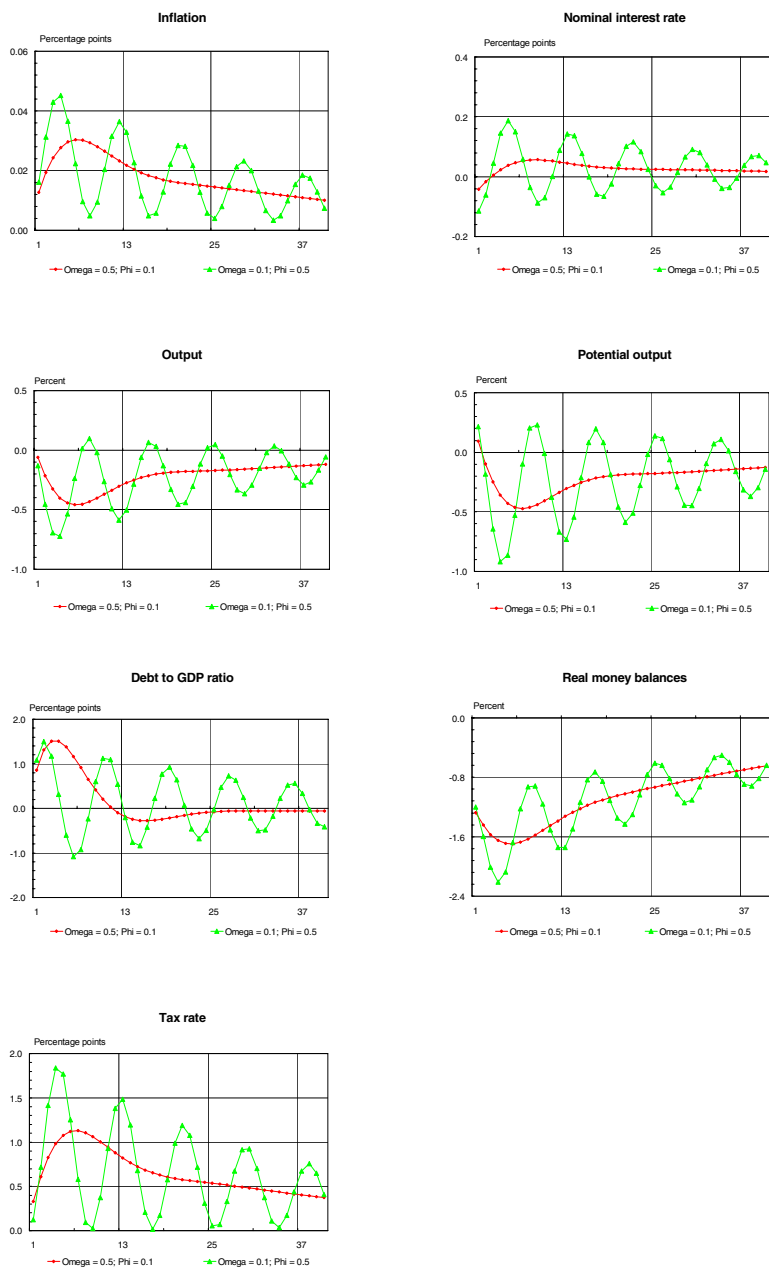
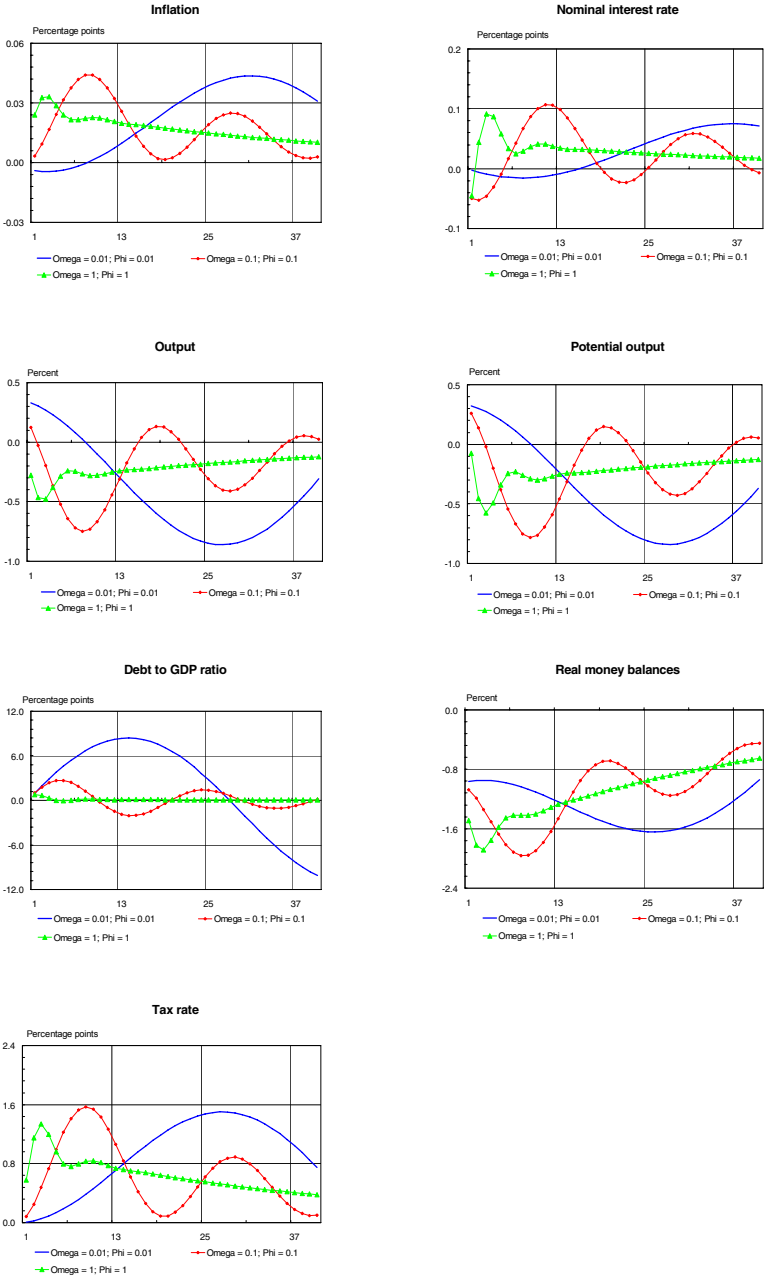
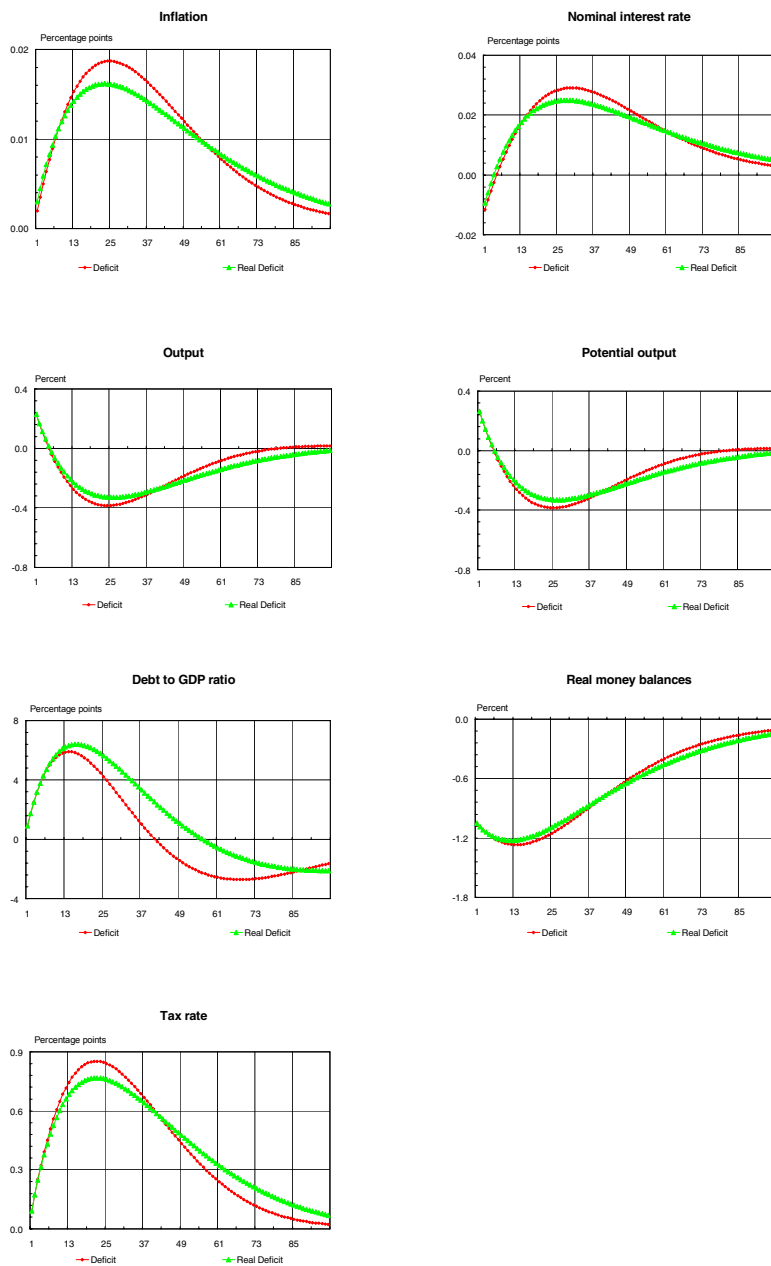


Figure 9: Government consumption shock with composite rule, deviations from baseline



nominal interest rate rises are smaller than with the accounting deficit rule. The difference in impulse response is relatively small for the different definitions of deficit. Figure 13 shows that the difference in impulse response is even smaller with the technology shock than with the government spending shock. It could be said that the SGP definition of deficit performs as well as the economic definition based on the government budget constraint. For simulations we have used the real deficit-to-GDP target $\psi_3 = 0.015$, which results in the same debt-to-GDP ratio in the steady state as with the accounting deficit rule.

Figure 10: Government consumption shock, deficit rule versus real deficit rule, deviations from baseline



4 Conclusions

Using a model without supply-side channel for fiscal policy, one comes to a dichotomy: only the active monetary policy with passive fiscal policy or passive monetary policy with active fiscal policy regimes are consistent with dynamic stability of the economy. In this chapter we used a model with a supply-side channel for fiscal policy by defining potential output endogenously and reached a different conclusion. As noted earlier, active monetary policy is consistent with the Taylor principle, ie the interest rate reacts more than one-for-one to inflation. An active fiscal policy is one that it is not constrained by budgetary conditions, whereas a passive fiscal policy must generate sufficient tax revenues to balance the budget.

Using different fiscal policy rules, we showed that the fiscal policy rule based on debt results in non-determinate solution, with active monetary policy. The debt rule results in a determinate solution only if monetary policy is passive and if the fiscal policy parameter gets large positive or negative values. Hence we conclude that the debt rule results in a determinate solution for passive fiscal and monetary policy.

The fiscal policy rule based on the SGP definition of budget deficit results in a determinate solution for a wide range of positive parameter values consistent with active monetary policy. We claim that fiscal policy can even be active with an active monetary policy and still be consistent with the dynamic stability of the economy. Hence we conclude that the distortionary tax rate creating a supply side channel for policy changes the interpretation of active and passive monetary-fiscal policy regimes, and it is possible to have an active monetary-fiscal policy regime with government deficit-based fiscal policy rule.

The SGP sets requirements for both debt-to-GDP and deficit-to-GDP ratios. By forming a fiscal policy rule by combining the two, we can say that by putting more weight on deficit than debt tends to reduce the cyclicity of the economy's dynamic responses to shocks to government spending and to technology. Cyclicity decreases also as the sum of weights on debt and deficit increases. At the same time, the tax rate response to the government expenditure shock becomes so large that it reduces output also in the short run. This also happens with the deficit and real deficit rules when the value of the fiscal policy rule parameter is large enough, ie if the fiscal policy is passive. With passive fiscal policy, an expansionary

government spending shock actually reduces output and causes more inflation than does active fiscal policy with the same shock. On the other hand, for low values of the fiscal policy parameter, the debt increases initially and causes the tax rate to rise in the future and leads to a debt-driven cycle for the economy. The larger the fiscal policy parameter, the more closely the tax rate reflects the pattern of shocks.

The SGP definition of deficit performs as well as the real deficit based on the real government flow budget constraint. Responses to government spending and technology shocks are almost identical for output, inflation and nominal interest rates. The only differences are in the debt-to-GDP ratio and the tax rate responses. These differences, however, are insignificant.

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A Appendix. Deficit rule

The system is given by output equation (A.1), real money balances equation (A.2), inflation equation (A.3), potential output equation (A.5), government consumption equation (A.4), interest rate rule equation (A.6), government budget constraint equation (A.7) and deficit rule for tax rate equation (A.8). We use the log-linearisation techniques¹⁰ in Uhlig (1999) to centre government budget constraint (2.34) and tax rule for deficit (3.1) around constant steady state, and move them one period forward. We also write the Taylor rule, potential output, government consumption and Phillips curve equations as deviations from the steady state. The system can be written as

$$\hat{y}_t = E_t \hat{y}_{t+1} + \frac{\bar{g}}{\bar{y}} [\hat{g}_t - E_t \hat{g}_{t+1}] - \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} (\hat{R}_t - \hat{\pi}_{t+1}), \quad (\text{A.1})$$

$$\hat{m}_t = \frac{\bar{y}}{\bar{c}} \hat{y}_t - \frac{\bar{g}}{\bar{c}} \hat{g}_t - \frac{1}{\sigma} \hat{R}_t, \quad (\text{A.2})$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + a \left[\left(\sigma \frac{\bar{y}}{\bar{c}} + \lambda \right) (\hat{y}_t - \hat{y}_t^*) \right], \quad (\text{A.3})$$

$$\rho^g \hat{g}_t - \rho^g \hat{y}_t = \hat{g}_{t+1} - \hat{y}_{t+1} + \hat{\varepsilon}_t^g, \quad (\text{A.4})$$

$$\hat{y}_t^* = \frac{\sigma \frac{\bar{g}}{\bar{c}}}{\sigma \frac{\bar{y}}{\bar{c}} + \lambda} \hat{g}_t - \frac{1}{\sigma \frac{\bar{y}}{\bar{c}} + \lambda} \hat{\tau}_t + \hat{\varepsilon}_t^{y^*}, \quad (\text{A.5})$$

$$\hat{R}_t = (1 + \eta_1) \hat{\pi}_t + \eta_2 (\hat{y}_t - \hat{y}_t^*), \quad (\text{A.6})$$

$$\begin{aligned} & \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \left(\frac{1}{\bar{R} - \bar{\pi}} + 1 \right) \right] \hat{b}_t \\ + & \frac{\bar{m}}{\bar{y}} \left(\frac{1}{\bar{\tau}} - \frac{\bar{\pi}}{\bar{\tau}} \right) \hat{m}_t + \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \frac{\bar{R}}{\bar{R} - \bar{\pi}} \right] \hat{R}_t = \\ & \hat{y}_{t+1} + \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \frac{\bar{\pi}}{\bar{R} - \bar{\pi}} + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} \right] \hat{\pi}_{t+1} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \hat{g}_{t+1} \\ & + \frac{1 \bar{m}}{\bar{\tau} \bar{y}} \hat{m}_{t+1} + \left[\left(1 + \frac{\bar{\pi} \bar{m}}{\bar{\tau} \bar{y}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \frac{1}{\bar{R} - \bar{\pi}} \right] \hat{b}_{t+1} + \hat{\tau}_{t+1}, \end{aligned} \quad (\text{A.7})$$

¹⁰In log-linearisation we denote $c_t = \bar{c} e^{\hat{c}_t} \approx \bar{c} (1 + \hat{c}_t)$ and $\tau_t y_t = \bar{\tau} \bar{y} e^{\hat{\tau}_t + \hat{y}_t} \approx \bar{\tau} \bar{y} (1 + \hat{\tau}_t + \hat{y}_t)$. By using the steady state conditions, the coefficients can be eliminated.

$$\begin{aligned}
& \frac{1}{\Omega} \widehat{\tau}_t + \left(1 + \frac{\psi_1}{\bar{\tau}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \widehat{b}_t = \\
& \left(1 + \frac{\psi_1}{\bar{\tau}} \right) \widehat{y}_{t+1} - \left(\frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \widehat{g}_{t+1} - \left(1 + \frac{\psi_1}{\bar{\tau}} - \frac{1 \bar{g}}{\bar{\tau} \bar{y}} \right) \widehat{R}_{t+1} \\
& + \left(\frac{1 + \Omega}{\Omega} \right) \widehat{\tau}_{t+1}.
\end{aligned} \tag{A.8}$$

We solve for the steady state tax rate by setting the steady state government budget constraint equal to the steady state deficit rule. The tax rate is then

$$\bar{\tau} = \frac{\bar{R} - \bar{\pi}}{\bar{\pi}} \psi_1 - \frac{\bar{R} \left(\frac{\bar{\pi} \bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right)}{\bar{\pi}} - \frac{\bar{R} - \bar{\pi} \bar{g}}{\bar{\pi} \bar{y}}. \tag{A.9}$$

After some substitutions we can write the eight-equation system in five equations. Then to write the system in state-space form. We define

$$\begin{aligned}
\widehat{X}'_t &= \begin{bmatrix} \widehat{y}_t & \widehat{\pi}_t \end{bmatrix}, \\
\widehat{x}'_t &= \begin{bmatrix} \widehat{g}_t & \widehat{b}_t & \widehat{\tau}_t \end{bmatrix}, \\
\epsilon &= \begin{bmatrix} \epsilon_t^{y^*} & \epsilon_t^g \end{bmatrix},
\end{aligned} \tag{A.10}$$

where \widehat{X}'_t is the vector of non-predetermined variables and \widehat{x}'_t the vector of predetermined variables. The reduced form can be written

$$A \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = B \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + C \epsilon, \tag{A.11}$$

or

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = M \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + N \epsilon, \tag{A.12}$$

where $M = A^{-1}B$. We omit the matrix N . The matrices A and B can be written

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & a_{15} \\ a_{21} & a_{22} & a_{23} & 0 & a_{25} \\ a_{31} & 0 & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ 0 & 0 & 0 & a_{54} & a_{55} \end{bmatrix}, B = \begin{bmatrix} b_{11} & b_{12} & b_{13} & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ b_{31} & 0 & b_{33} & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & 0 & b_{55} \end{bmatrix},$$

where

$$a_{11} = \left[1 + \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} \eta_2 \right], a_{12} = \left[\frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} (1 + \eta_1) \right], a_{13} = - \left[\frac{\bar{g}}{\bar{y}} + \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} \eta_2 \frac{\frac{\sigma \bar{g}}{\bar{c}}}{\sigma \frac{\bar{g}}{\bar{c}} + \lambda} \right],$$

$$\begin{aligned}
a_{15} &= \left[\frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \frac{\bar{y}}{c} + \lambda} \right], a_{21} = \left[-a \left(\sigma \frac{\bar{y}}{c} + \lambda \right) \right], a_{22} = 1, \\
a_{23} &= \left[a \left(\sigma \frac{\bar{y}}{c} + \lambda \right) \frac{\sigma \frac{\bar{y}}{c}}{\sigma \frac{\bar{y}}{c} + \lambda} \right], a_{25} = - \left[a \left(\sigma \frac{\bar{y}}{c} + \lambda \right) \frac{1}{\sigma \frac{\bar{y}}{c} + \lambda} \right], \\
a_{31} &= -\rho^g, a_{33} = \rho^g, \\
a_{41} &= \left[\frac{\bar{m}}{\bar{y}} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \left(\frac{\bar{y}}{c} - \frac{1}{\sigma} \eta_2 \right) + \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} \eta_2 \right], \\
a_{42} &= \left[-\frac{\bar{m}}{\bar{y}} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \frac{1}{\sigma} (1 + \eta_1) + \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} (1 + \eta_1) \right], \\
a_{43} &= \left[\frac{\bar{m}}{\bar{y}} \left(\frac{1-\bar{\pi}}{\bar{\tau}} \right) \left(\frac{1}{\sigma} \eta_2 \frac{\sigma \frac{\bar{y}}{c}}{\sigma \frac{\bar{y}}{c} + \lambda} - \frac{\bar{g}_t}{\bar{c}_t} \right) - \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} \eta_2 \frac{\sigma \frac{\bar{y}}{c}}{\sigma \frac{\bar{y}}{c} + \lambda} \right], \\
a_{44} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \left(\frac{1}{\bar{R}-\bar{\pi}} + 1 \right) \right], \\
a_{45} &= \left[\frac{\bar{m}}{\bar{y}} \left(\frac{1}{\bar{\tau}} - \frac{\bar{\pi}}{\bar{\tau}} \right) \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \frac{\bar{y}}{c} + \lambda} + \left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{R}}{\bar{R}-\bar{\pi}} \eta_2 \frac{1}{\sigma \frac{\bar{y}}{c} + \lambda} \right], \\
a_{54} &= \left(1 + \frac{\psi_1}{\bar{\tau}} - \frac{1}{\bar{\tau}} \frac{\bar{g}}{\bar{y}} \right), a_{55} = \frac{1}{\Omega}, \\
b_{11} &= 1, b_{12} = \frac{\bar{c}_t}{\bar{y}_t} \frac{1}{\sigma}, b_{13} = -\frac{\bar{g}_t}{\bar{y}_t}, b_{22} = \beta, b_{31} = -1, b_{33} = 1, \\
b_{41} &= \left[1 + \frac{1}{\bar{\tau}} \frac{\bar{m}}{\bar{y}} \left(\frac{\bar{y}_t}{\bar{c}_t} - \frac{1}{\sigma} \eta_2 \right) \right], \\
b_{42} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{\bar{\pi}}{\bar{R}-\bar{\pi}} + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{m}}{\bar{y}} \frac{1}{\sigma} (1 + \eta_1) \right) \right], \\
b_{43} &= \left[\frac{1}{\bar{\tau}} \left(\frac{\bar{m}}{\bar{y}} \left(\frac{1}{\sigma} \eta_2 \frac{\sigma \frac{\bar{y}}{c}}{\sigma \frac{\bar{y}}{c} + \lambda} - \frac{\bar{g}_t}{\bar{c}_t} \right) - \frac{\bar{g}}{\bar{y}} \right) \right], \\
b_{44} &= \left[\left(1 + \frac{1}{\bar{\tau}} \left(\bar{\pi} \frac{\bar{m}}{\bar{y}} - \frac{\bar{g}}{\bar{y}} \right) \right) \frac{1}{\bar{R}-\bar{\pi}} \right], \\
b_{45} &= \left[1 - \frac{1}{\bar{\tau}} \frac{\bar{m}}{\bar{y}} \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \frac{\bar{y}}{c} + \lambda} \right], \\
b_{51} &= \left[1 + \frac{\psi_1}{\bar{\tau}} - \left(1 + \frac{\psi_1}{\bar{\tau}} - \frac{1}{\bar{\tau}} \frac{\bar{g}}{\bar{y}} \right) \eta_2 \right], \\
b_{52} &= - \left[\left(1 + \frac{\psi_1}{\bar{\tau}} - \frac{1}{\bar{\tau}} \frac{\bar{g}}{\bar{y}} \right) (1 + \eta_1) \right], \\
b_{53} &= \left[\left(1 + \frac{\psi_1}{\bar{\tau}} - \frac{1}{\bar{\tau}} \frac{\bar{g}}{\bar{y}} \right) \eta_2 \frac{\sigma \frac{\bar{y}}{c}}{\sigma \frac{\bar{y}}{c} + \lambda} - \left(\frac{1}{\bar{\tau}} \frac{\bar{g}}{\bar{y}} \right) \right], \\
b_{55} &= \left[\left(\frac{1+\Omega}{\Omega} \right) - \left(1 + \frac{\psi_1}{\bar{\tau}} - \frac{1}{\bar{\tau}} \frac{\bar{g}}{\bar{y}} \right) \eta_2 \frac{1}{\sigma \frac{\bar{y}}{c} + \lambda} \right].
\end{aligned}$$

B Appendix. Debt rule

We centre the debt rule (3.5) around the constant steady state to obtain

$$\frac{\phi \bar{m}}{\bar{\tau} \bar{y}} \widehat{m}_t + \frac{\phi}{\bar{\tau}} \left(\psi_2 - \frac{\bar{m}}{\bar{y}} \right) \widehat{b}_t + \widehat{\tau}_t = \frac{\phi}{\bar{\tau}} \psi_2 \widehat{y}_{t+1} + \widehat{\tau}_{t+1}. \quad (\text{B.1})$$

We solve for the steady state tax rate by setting the steady state government budget constraint equal to the steady state debt rule. The tax rate is then

$$\bar{\tau} = (\bar{R} - \bar{\pi}) \psi_2 - \bar{R} \frac{\bar{m}}{\bar{y}} + \frac{\bar{g}}{\bar{y}}. \quad (\text{B.2})$$

Define

$$\begin{aligned} \widehat{X}'_t &= \begin{bmatrix} \widehat{y}_t & \widehat{\pi}_t \end{bmatrix}, \\ \widehat{x}'_t &= \begin{bmatrix} \widehat{g}_t & \widehat{b}_t & \widehat{\tau}_t \end{bmatrix}, \\ \epsilon &= \begin{bmatrix} \epsilon_t^{y^*} & \epsilon_t^g \end{bmatrix}, \end{aligned} \quad (\text{B.3})$$

where \widehat{X}'_t is the vector of non-predetermined variables and \widehat{x}'_t the vector of predetermined variables. The reduced form can be written

$$A \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = B \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + C \epsilon, \quad (\text{B.4})$$

or

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = M \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + N \epsilon, \quad (\text{B.5})$$

where $M = A^{-1}B$. We omit the matrix N . The matrices A and B can be written

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & a_{15} \\ a_{21} & a_{22} & a_{23} & 0 & a_{25} \\ a_{31} & 0 & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix}, B = \begin{bmatrix} b_{11} & b_{12} & b_{13} & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ b_{31} & 0 & b_{33} & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & 0 & 0 & 0 & b_{55} \end{bmatrix},$$

where $a_{11} - a_{45}$ and $b_{11} - b_{45}$ are like above and

$$\begin{aligned} a_{51} &= \left[\frac{\phi \bar{m}}{\bar{\tau} \bar{y}} \left(\frac{\bar{y}}{\bar{c}} - \frac{1}{\sigma} \eta_2 \right) \right], a_{52} = - \left[\frac{\phi \bar{m}}{\bar{\tau} \bar{y}} \frac{1}{\sigma} (1 + \eta_1) \right], \\ a_{53} &= \left[\frac{\phi \bar{m}}{\bar{\tau} \bar{y}} \left(\frac{1}{\sigma} \eta_2 \frac{\sigma \bar{g}}{\sigma \bar{y} + \lambda} - \frac{\bar{g}_t}{\bar{c}_t} \right) \right], a_{54} = \left[\frac{\phi}{\bar{\tau}} \left(\psi_2 - \frac{\bar{m}}{\bar{y}} \right) \right], \\ a_{55} &= \left[1 - \frac{\phi \bar{m}}{\bar{\tau} \bar{y}} \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \bar{y} + \lambda} \right], \\ b_{51} &= \frac{\phi}{\bar{\tau}} \psi_2, b_{55} = 1. \end{aligned}$$

C Appendix. Composite rule

We centre the composite rule (3.9) around the constant steady state to obtain

$$\begin{aligned}
 & \frac{\phi \bar{m}}{\bar{\tau} \bar{y}} \widehat{m}_t + \left[\left(\frac{\bar{g}}{\bar{y}} - \bar{\tau} + \frac{\phi \bar{m}}{\bar{\Omega} \bar{y}} - (\psi_1 + \frac{\phi}{\bar{\Omega}} \psi_2) \right) \right. \\
 & \left. \left(\frac{\bar{\Omega} \bar{R}}{\bar{\tau}} + \frac{\phi}{\bar{\tau}} \right) \right] \widehat{b}_t + \widehat{\tau}_t \\
 = & \left[\bar{\Omega} + \bar{\Omega} \frac{\psi_1}{\bar{\tau}} + \phi \frac{\psi_2}{\bar{\tau}} \right] \widehat{y}_{t+1} - \left[\frac{\bar{\Omega} \bar{g}}{\bar{\tau} \bar{y}} \right] \widehat{g}_{t+1} - \\
 & \left[\left(\frac{\bar{g}}{\bar{y}} - \bar{\tau} + \frac{\phi \bar{m}}{\bar{\Omega} \bar{y}} - (\psi_1 + \frac{\phi}{\bar{\Omega}} \psi_2) \right) \frac{\bar{\Omega} \bar{R}}{\bar{\tau}} \right] \widehat{R}_{t+1} + (1 + \bar{\Omega}) \widehat{\tau}_{t+1}.
 \end{aligned} \tag{C.1}$$

We solve for the steady state tax rate by setting the steady state government budget constraint equal to the steady state debt rule. The tax rate is then

$$\bar{\tau} = \left[\frac{\bar{g}}{\bar{y}} + \frac{\phi \bar{m}}{\bar{\Omega} \bar{y}} - (\psi_1 + \frac{\phi}{\bar{\Omega}} \psi_2) - \frac{\bar{\pi} \bar{m}}{\bar{R} - \bar{\pi}} - \frac{\bar{g}}{\bar{y}} \right] \left[\frac{1}{\bar{R} - \frac{\phi}{\bar{\Omega}}} + \frac{1}{\bar{R} - \bar{\pi}} \right]^{-1}. \tag{C.2}$$

Define

$$\begin{aligned}
 \widehat{X}'_t &= \begin{bmatrix} \widehat{y}_t & \widehat{\pi}_t \end{bmatrix}, \\
 \widehat{x}'_t &= \begin{bmatrix} \widehat{g}_t & \widehat{b}_t & \widehat{\tau}_t \end{bmatrix}, \\
 \epsilon &= \begin{bmatrix} \epsilon_t^y & \epsilon_t^g \end{bmatrix},
 \end{aligned} \tag{C.3}$$

where \widehat{X}'_t is the vector of non-predetermined variables and \widehat{x}'_t the vector of predetermined variables. The reduced form can be written

$$A \begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = B \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + C \epsilon, \tag{C.4}$$

or

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{x}_t \end{bmatrix} = M \begin{bmatrix} E_t \widehat{X}_{t+1} \\ \widehat{x}_{t+1} \end{bmatrix} + N \epsilon, \tag{C.5}$$

where $M = A^{-1}B$. We omit the matrix N . The matrices A and B can be written

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & a_{15} \\ a_{21} & a_{22} & a_{23} & 0 & a_{25} \\ a_{31} & 0 & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix}, B = \begin{bmatrix} b_{11} & b_{12} & b_{13} & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ b_{31} & 0 & b_{33} & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & 0 & b_{55} \end{bmatrix},$$

where a_{11} to a_{45} and b_{11} to b_{45} are like above and

$$\begin{aligned} a_{51} &= \left[\frac{\phi \bar{m}}{\tau \bar{y}} \left(\frac{\bar{y}}{c} - \frac{1}{\sigma} \eta_2 \right) \right], a_{52} = - \left[\frac{\phi \bar{m}}{\tau \bar{y}} \frac{1}{\sigma} (1 + \eta_1) \right], \\ a_{53} &= \left[\frac{\phi \bar{m}}{\tau \bar{y}} \left(\frac{1}{\sigma} \eta_2 \frac{\sigma \bar{y}}{\sigma \bar{y} + \lambda} - \frac{\bar{y}}{c} \right) \right], a_{54} = \\ & \left[\left(\frac{\frac{\bar{y}}{\bar{y}} - \bar{\tau} + \frac{\phi \bar{m}}{\Omega \bar{y}} - (\psi_1 + \frac{\phi}{\Omega} \psi_2)}{R - \frac{\phi}{\Omega}} \right) \left(\frac{\Omega \bar{R}}{\tau} + \frac{\phi}{\tau} \right) \right], \\ a_{55} &= \left[1 - \frac{\phi \bar{m}}{\tau \bar{y}} \frac{1}{\sigma} \eta_2 \frac{1}{\sigma \bar{y} + \lambda} \right], \\ b_{51} &= \left[\Omega + \Omega \frac{\psi_1}{\tau} + \phi \frac{\psi_2}{\tau} - \left(\frac{\frac{\bar{y}}{\bar{y}} - \bar{\tau} + \frac{\phi \bar{m}}{\Omega \bar{y}} - (\psi_1 + \frac{\phi}{\Omega} \psi_2)}{R - \frac{\phi}{\Omega}} \right) \frac{\Omega \bar{R}}{\tau} \eta_2 \right], \\ b_{52} &= - \left[\left(\frac{\frac{\bar{y}}{\bar{y}} - \bar{\tau} + \frac{\phi \bar{m}}{\Omega \bar{y}} - (\psi_1 + \frac{\phi}{\Omega} \psi_2)}{R - \frac{\phi}{\Omega}} \right) \frac{\Omega \bar{R}}{\tau} (1 + \eta_1) \right], \\ b_{53} &= \left[\left(\frac{\frac{\bar{y}}{\bar{y}} - \bar{\tau} + \frac{\phi \bar{m}}{\Omega \bar{y}} - (\psi_1 + \frac{\phi}{\Omega} \psi_2)}{R - \frac{\phi}{\Omega}} \right) \frac{\Omega \bar{R}}{\tau} \eta_2 \frac{\sigma \bar{y}}{\sigma \bar{y} + \lambda} - \left(\frac{\Omega \bar{y}}{\tau} \right) \right], \\ b_{55} &= \left[(1 + \Omega) - \left(\frac{\frac{\bar{y}}{\bar{y}} - \bar{\tau} + \frac{\phi \bar{m}}{\Omega \bar{y}} - (\psi_1 + \frac{\phi}{\Omega} \psi_2)}{R - \frac{\phi}{\Omega}} \right) \frac{\Omega \bar{R}}{\tau} \eta_2 \frac{1}{\sigma \bar{y} + \lambda} \right]. \end{aligned}$$

Figure 11: Technology shock with composite rule, deviations from baseline

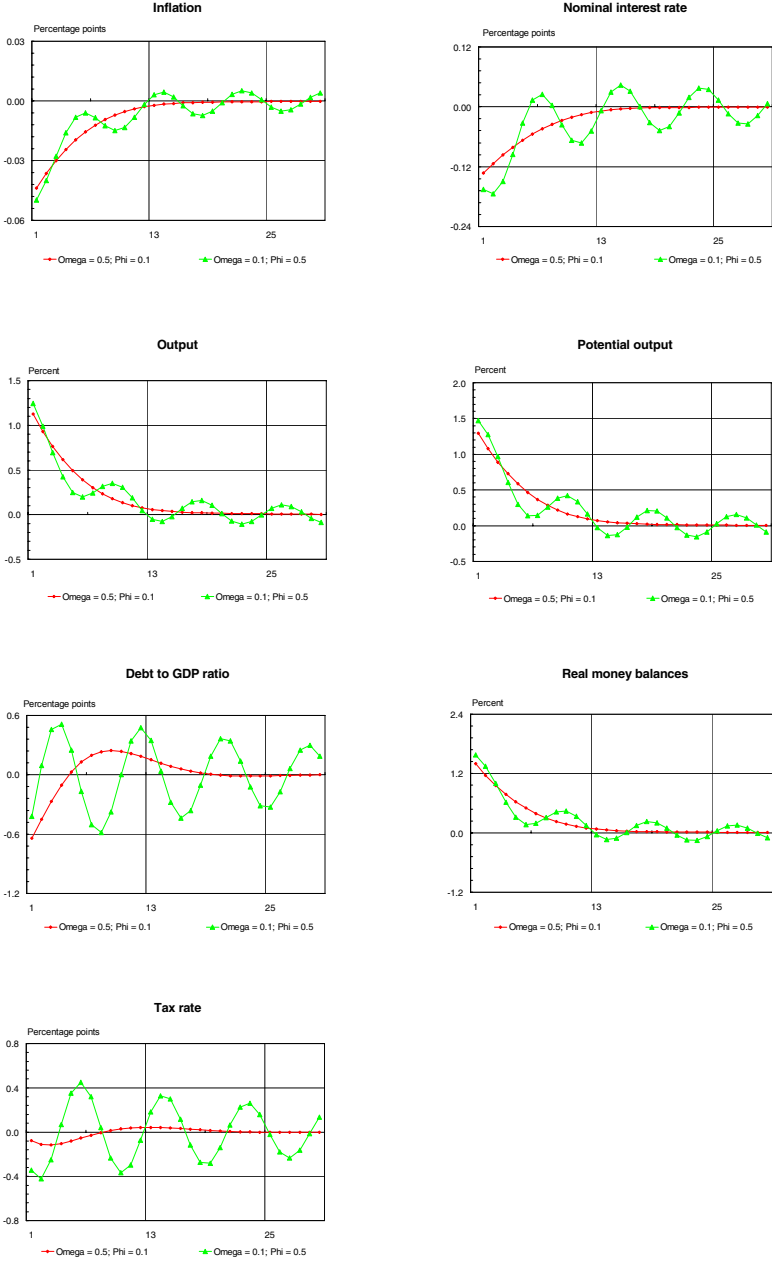


Figure 12: Technology shock with composite rule, deviations from baseline

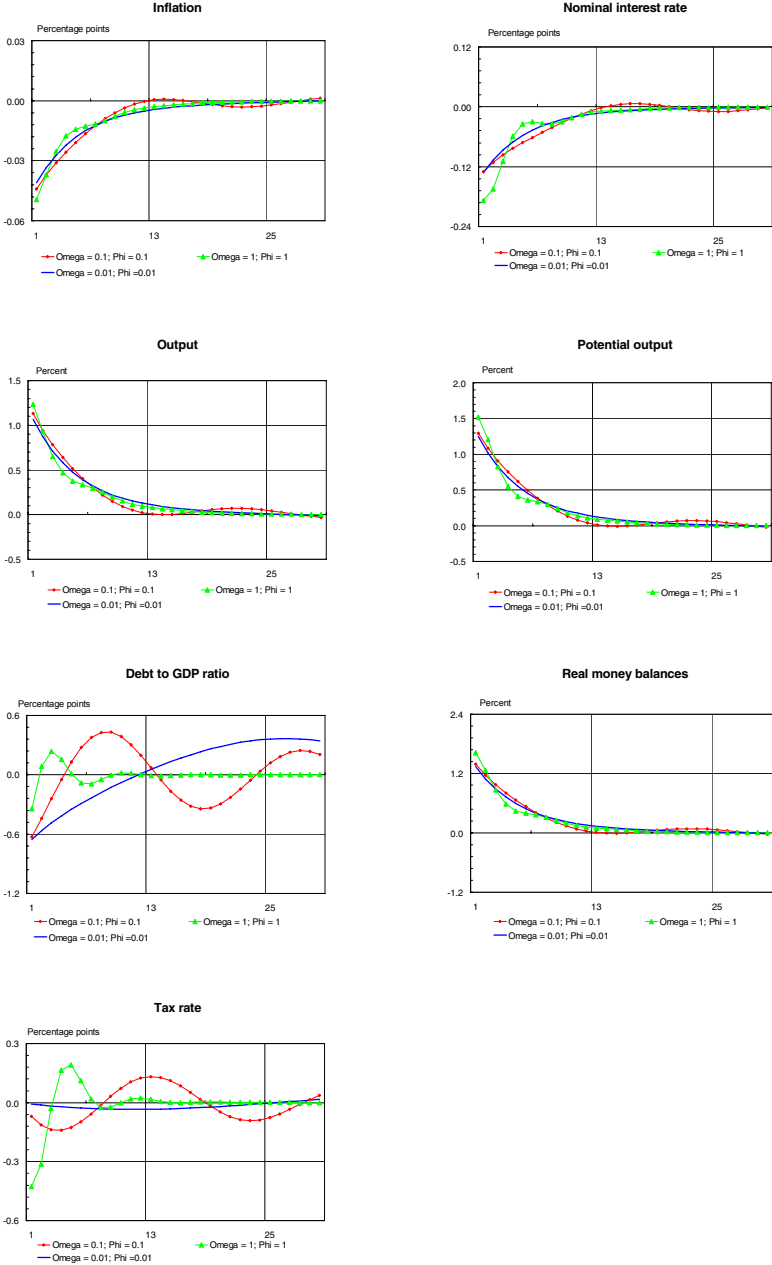
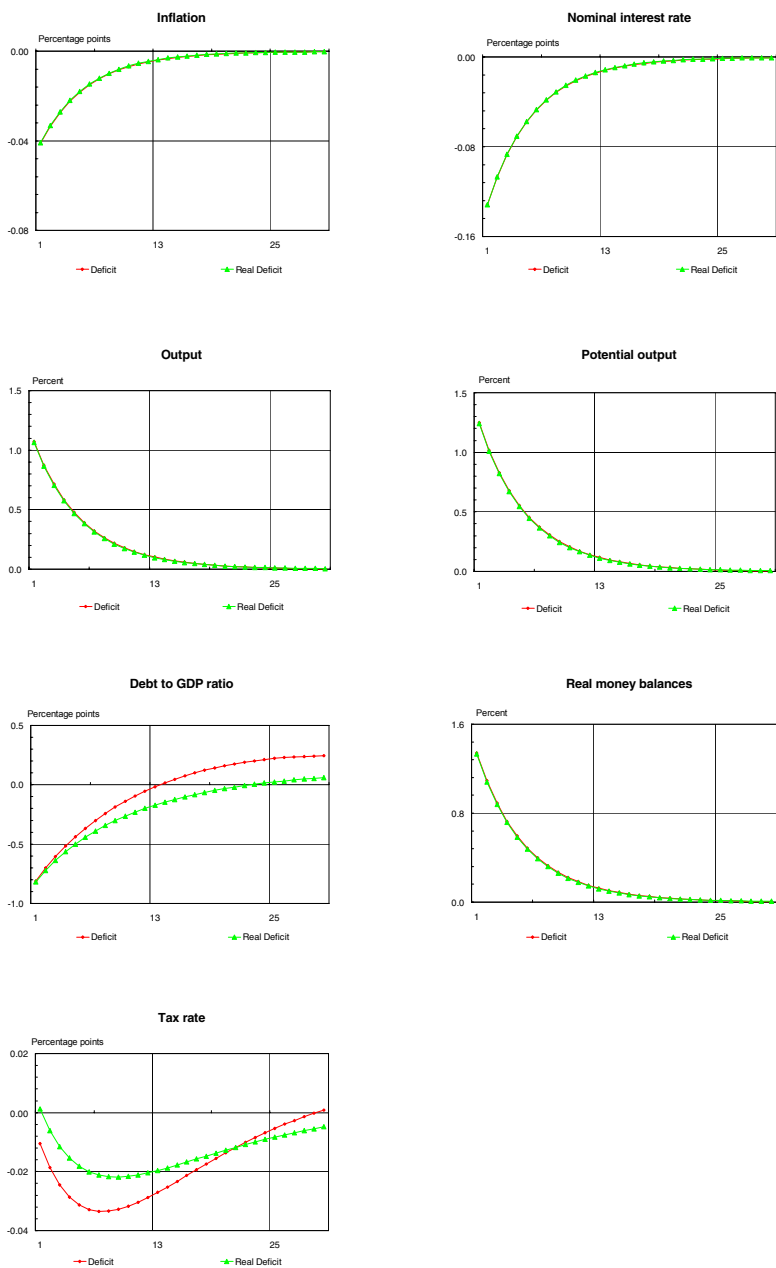


Figure 13: Technology shock, deficit rule versus real deficit rule, deviations from baseline



Chapter 4

Monetary consequences of alternative fiscal policy rules

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Abstract

In this chapter we analyse the monetary impact of alternative fiscal policy rules using the debt and the deficit, both cited as measures of fiscal policy performance in the Stability and Growth Pact (SGP). We use a New Keynesian model, with distortionary taxation and an endogenously defined output gap. The economy is hit by two fundamental shocks: demand and supply shocks, which are orthogonal to each other. Monetary policy is conducted by an independent central bank that optimises. Under discretionary monetary policy the size of inflation bias depends on the fiscal policy regime. Using the timeless perspective approach to precommitment, output persistence increases compared to the discretionary case. The result holds with the alternative fiscal policy rules, and inflation and output persistence reflect the economic data. With the deficit rules, the autocorrelation of the tax rate is near unity irrespective of monetary policy regime and of fiscal policy parameters and targets. Thus we revive Barro's (1979) random walk result with deficit rules.

1 Introduction

The literature on monetary policy has focused on how monetary policy can stabilise the economy under shocks, mainly technology shocks. Benhabib and Wen (2004) claim that an aggregate demand shock is able to explain the actual fluctuation in RBC models. From a Keynesian point of view, demand shocks are thought to be important generating business cycles because the slow adjustment in prices may cause resources to be under-utilised, enabling the expansion of output without an increase in marginal costs in response to higher aggregate demand.

The more-detailed description of fiscal and monetary policies was reintroduced by Sargent and Wallace (1981) in their unpleasant monetaristic arithmetic already in the eighties. Subsequently, there has been a burgeoning literature on optimal monetary and fiscal policy models in which the behaviour of both monetary and fiscal policy-makers is based on optimisation, so that the fiscal authority affects the price level determination.¹

In this chapter we analyse the monetary impacts of alternative fiscal policy rules with both demand and supply shocks. We do this in a New Keynesian model with distortionary taxation and sticky prices and a simple description of the public sector. We derive endogenous potential output as reacting to fiscal policy variables and hence fiscal policy has not only demand- but also supply-side effects. Benigno and Woodford (2004a and 2004b) consider the appropriate stabilisation objectives in a model in which the output target is defined to respond to real disturbances and hence the output gap is relevant to the policy authority.

Monetary policy is conducted by an independent central bank that optimises, whereas the fiscal authority must follow a rule. The society delegates monetary policy to an independent and conservative central bank.² By independence we mean that the central bank has full control over the monetary policy instruments and decides how much public debt will be monetised. However, as shown in Schmitt-Grohé and Uribe (2004b), even with a small degree of price stickiness optimal inflation volatility is close to zero. We do not base fiscal policy

¹See eg Chari and Kehoe (1999), Chari, Christiano and Kehoe (1991 and 1994), Benigno and Woodford (2003) and Schmitt-Grohé and Uribe (2003, 2004a and 2004b), Siu (2004).

²See eg Barro and Gordon (1983), Rogoff (1985) and Svensson (1997).

behaviour on optimisation, since we are more interested in different fiscal policy regimes.

We formulate alternative fiscal policy rules using debt and deficit, both cited as measures of fiscal policy performance in the Stability and Growth Pact (SGP). The output gap reacts to both demand and supply, and this opens another determination channel for inflation bias. In Siu (2004) fiscal policy is aimed at balancing spending shocks by absorbing inflation benefits. Schmitt-Grohé and Uribe (2003, 2004a and 2004b) find that fiscal policy in a model with distortionary taxation affects the determination of steady state inflation and inflation volatility.

Siu (2004) states that an important result of the optimal policy literature is the prescription of policies for smoothing tax distortions over time and states of nature. When governments finance stochastic government spending by taxing labour income and issuing one-period debt, state-contingent returns on that debt allow for roughly constant tax rates, as in Lucas and Stokey (1983) and Chari et al (1991 and 1994). In contrast to Barro's (1979) random walk result, Chari et al show that with flexible prices these variables inherit the serial correlation of the model's underlying shocks.

Siu (2004) finds that the serial correlation properties of optimal tax rates and real government debt differ for flexible and sticky price models. Siu also finds that with sticky prices the autocorrelations of these are close to unity regardless of persistence in the shock process, thus lending some support to Barro's (1979) random walk result. The finding is similar to Aiyagari et al (2002), who consider optimal policy in a model with incomplete markets.

We show that under discretionary monetary policy, the size of inflation bias depends on the fiscal policy regime when fiscal policy follows a rule. If the central bank is able to commit, inflation bias disappears. More importantly, using optimality from a timeless perspective for monetary policy precommitment Woodford (2003) increases output persistence significantly compared to the discretionary case. We also find support for Barro's (1979) random walk result with deficit rules for both commitment-based and discretionary monetary policy, irrespective of fiscal policy regime. With the debt rules, Barro's result does not hold for high debt-to-GDP target values, and the tax rate inherits the stochastic nature of the underlying shocks.

The chapter is organised as follows. Section 2 describes the economy, ie the behaviour of household and firm. Policy targets are

set for both central bank and fiscal authority. In Section 3 we set up our simulation procedure and present all the results. Section 4 concludes.

2 The model

We consider a production economy with a continuum of identical firms, an infinitely-lived representative consumer, and a public sector. There is a composite consumption good c_t and a public good g_t that satisfy the resource constraint

$$y_t = c_t + g_t, \quad (2.1)$$

where y_t is aggregate production. The available production technology is represented as a linear production function

$$y_t = Al_t, \quad (2.2)$$

where l_t is labour input and $A = \zeta_t e^{\alpha * Time}$ describes technological progress. Stochastic fluctuations around the deterministic trend in the log of productivity $z_t \equiv \ln \zeta_t$ are given by an exogenous AR(1) process

$$z_t = \rho z_{t-1} + \nu_t, \quad |\rho| < 1, \quad \nu_t = N(0, \sigma_\nu^2). \quad (2.3)$$

A representative household maximises the utility function

$$E_t \sum_{t=0}^{\infty} \delta^t u(c_t, m_t, l_t; g_t) \quad (2.4)$$

subject to the budget constraint

$$c_t + m_t - (1 - \pi_t)m_{t-1} + b_t \leq (1 + r_{t-1})b_{t-1} + (1 - \tau_t)(w_t l_t + \Pi_t), \quad (2.5)$$

where m_t is real money balances, b_t government bonds held by the household in real terms, w_t the real gross wage rate, Π_t the firm's real profit received by the household, and τ_t the income tax rate.³ The household's discount factor is δ , and E_t is the expectation operator conditional on information available in period t . We assume that the utility function $u(c_t, m_t, l_t; g_t)$ is continuous, increasing and concave.

The first-order conditions are

$$u_c(c_t, m_t, l_t; g_t) - \xi_t = 0, \quad (2.6)$$

$$u_m(c_t, m_t, l_t; g_t) - \xi_t + \delta E_t [\xi_{t+1} (1 - \pi_{t+1})] = 0, \quad (2.7)$$

³Inflation π is defined as $\frac{P_t - P_{t-1}}{P_t} = \pi_t$, which implies that $1 - \pi_t = \frac{P_{t-1}}{P_t}$. The real interest rate r_t satisfies $1 + r_t = (1 + R_t)(1 - \pi_{t+1})$, where R_t is the nominal interest rate and π_{t+1} the expected inflation rate.

$$u_l(c_t, m_t, l_t; g_t) + \xi_t w_t(1 - \tau_t) = 0, \quad (2.8)$$

$$\xi_t = \delta E_t \xi_{t+1} (1 + r_t), \quad (2.9)$$

where ξ is the Lagrangean multiplier and subscripts indicate partial derivatives. Combining equations, the first-order conditions yield

$$E_t \left[\frac{u_c(c_{t+1}, m_{t+1}, l_{t+1}; g_{t+1})}{u_c(c_t, m_t, l_t; g_t)} \right] = \frac{1}{(1 + r_t)\delta}, \quad (2.10)$$

$$u_m(c_t, m_t, l_t; g_t) = u_c(c_t, m_t, l_t; g_t) \frac{R_t}{1 + R_t}, \quad (2.11)$$

$$u_l(c_t, m_t, l_t; g_t) = -u_c(c_t, m_t, l_t; g_t) w_t(1 - \tau_t). \quad (2.12)$$

Now we assume a periodic utility function written as $u(c_t, m_t, l_t; g_t) = \frac{c_t^{1-\sigma}}{1-\sigma} + \frac{\Gamma m_t^{1-\sigma}}{1-\sigma} - \frac{l_t^{1+\lambda}}{1+\lambda} + f(g_t)$, where $\sigma \geq 0$ is the elasticity of intertemporal substitution of consumption and Γ is a positive constant. $\lambda \geq 0$ is the inverse of the Frisch elasticity of labour supply. Using the periodical utility function, the first-order conditions can be rewritten as

$$c_t^{-\sigma} = E_t c_{t+1}^{-\sigma} (1 + r_t) \delta, \quad (2.13)$$

$$\Gamma m_t^{-\sigma} = c_t^{-\sigma} \frac{R_t}{1 + R_t}, \quad (2.14)$$

$$-l_t^\lambda = -c_t^{-\sigma} w_t (1 - \tau_t). \quad (2.15)$$

Combining (2.13) and (2.14) with the resource constraint yields⁴

$$\ln y_t = E_t \ln y_{t+1} + \frac{\bar{y}}{\bar{y}} [\ln g_t - E_t \ln g_{t+1}] - \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} r_t - \frac{\bar{c}}{\bar{y}} \frac{1}{\sigma} \ln \delta, \quad (2.16)$$

$$\ln m_t = \frac{\bar{y}}{\bar{c}} \ln y_t - \frac{\bar{y}}{\bar{c}} \ln g_t - \frac{1}{\sigma} R_t + \frac{1}{\sigma} \ln \Gamma. \quad (2.17)$$

A representative profit maximising firm hires labour in the amount of l_t and produces and sells products in a monopolistically competitive goods market.⁵ The firm's nominal profit is

$$P_t \Pi_t = P_t y_t - P_t w_t l_t. \quad (2.18)$$

⁴First we loglinearise equations (2.13) and (2.14), following Uhlig (1999). Log-linearisation of (2.1) around the steady state yields $\hat{y}_t = \frac{\bar{c}}{\bar{y}} \hat{c}_t + \frac{\bar{y}}{\bar{y}} \hat{g}_t$. Since we want to write IS and LM in (log) levels, we apply the definition of the logarithmic deviations, eg for output $\hat{y}_t = \ln\left(\frac{y_t}{\bar{y}_t}\right)$, and the steady state conditions. See Railavo (2003) for details.

⁵We assume labour market is perfectly competitive.

We can write the firm's real marginal cost using the production technology (2.2) as

$$\frac{\partial}{\partial y_t} \left[w_t \left(\frac{y_t}{A} \right) \right] = w_t \frac{1}{A} = mc_t. \quad (2.19)$$

Substituting the equilibrium wage $w_t = c_t^\sigma \left(\frac{y_t}{A} \right)^\lambda (1 - \tau_t)^{-1}$ into the marginal cost equation yields

$$c_t^\sigma y_t^\lambda A^{-(1+\lambda)} (1 - \tau_t)^{-1} = mc_t. \quad (2.20)$$

Taking natural logarithms of (2.20) and using the description of technological development $A = \zeta_t e^{\alpha * Time}$ yields

$$\lambda \ln y_t - (1 + \lambda) \ln \zeta_t - (1 + \lambda) \alpha * Time + \sigma \ln c_t - \ln (1 - \tau_t) = \ln mc_t. \quad (2.21)$$

In a flexible price equilibrium, nominal price equals mark-up times nominal marginal cost.⁶ The equilibrium conditions yield the long-run supply function⁷

$$\ln y_t^f = \frac{\sigma \bar{y}}{\kappa} \ln g_t + \frac{1 + \lambda}{\kappa} \alpha * Time + \frac{1}{\kappa} \ln (1 - \tau_t) + \varepsilon_t^{y^f}, \quad (2.22)$$

where y_t^f is the level of flexible price output with a distortionary tax rate, and we denote $\kappa = \left(\sigma \frac{\bar{y}}{c} + \lambda \right)$ and $\varepsilon_t^{y^f} = \frac{1 + \lambda}{\kappa} z_t$.⁸

To find the firm's pricing equation, we follow Rotemberg (1987). We assume that there are costs to the firm when it changes prices. This assumption introduces price stickiness and reflects the empirical aspect that individual price setting is lumpy. The forward-looking firm sets prices by minimising the quadratic loss function

$$\frac{1}{2} E_t \sum_{j=0}^{\infty} \beta^j \left[(\ln P_{t+j} - \ln P_{t+j-1})^2 + a (\ln P_{t+j} - \ln P_{t+j}^*)^2 \right], \quad (2.23)$$

where $\beta = \frac{1}{(1+r)}$, $r > 0$ is the discount factor and a an adjustment cost parameter. Taking the first-order conditions of (2.23), rearranging

⁶In real terms $mc_t = \frac{1}{\mu}$, where μ is the mark-up. See Chapter 2 for a detailed derivation of equation (2.22).

⁷Combine (2.21) with the log-linearised resource constraint. Using the steady state condition of (2.21) we can again convert the loglinearised equation into (log) levels form.

⁸Note that $z_t \equiv \ln \zeta_t$.

terms and using the supply function (2.22), the New Keynesian Phillips curve becomes

$$\pi_t = \beta E_t \pi_{t+1} + a\kappa \left(\ln y_t - \ln y_t^f \right). \quad (2.24)$$

Public sector behaviour is characterised by a budget constraint, an expenditure path, a monetary policy delegated to a central bank, and a fiscal policy rule. The intertemporal budget constraint for the policy authority links the debt and policy choices. The real flow budget constraint can be written as

$$b_t + \tau_t y_t + \pi_t m_{t-1} + m_t - m_{t-1} = (1 + r_{t-1}) b_{t-1} + g_t, \quad (2.25)$$

where b_t is government bonds, $\tau_t y_t$ tax revenue, m_t nominal money balances, r_t the real interest rate, and g_t government consumption. The policy authority balances its budget with new debt, taxes and seigniorage revenue ($\pi_t m_{t-1} + m_t - m_{t-1}$). The government taxes the income $y_t = w_t l_t + \Pi_t$ and τ_t is the income tax rate. The intertemporal government budget constraint, which sums up the expected budget surpluses, is given by

$$(1 + r) b_t \leq \sum \left(\frac{1}{1 + r_{t+i}} \right)^i (\pi_{t+i} m_{t-1+i} + m_{t+i} - m_{t-1+i} + \tau_{t+i} y_{t+i} - g_{t+i}). \quad (2.26)$$

Government consumption is characterised by an autoregressive process of a ratio to output, to ensure convergency of the solution

$$\frac{g_t}{y_t} = \rho^g \frac{g_{t-1}}{y_{t-1}} + (1 - \rho^g) \bar{\gamma} + \varepsilon_t^g, \quad |\rho^g| \leq 1, \quad \varepsilon_t^g = N(0, \sigma_{\varepsilon^g}^2), \quad (2.27)$$

where $\bar{\gamma}$ is a constant government consumption-to-GDP ratio. Innovations σ_ν^2 and $\sigma_{\varepsilon^g}^2$ of fundamental shocks are orthogonal to each other. This simultaneous link between government consumption and output may amplify some of the results, but is necessary for the constant steady state ratio between government consumption and output, since we have non-stationary government consumption and output paths.

Monetary policy is delegated to an independent central bank following Rogoff (1985). Optimal monetary policy is based on minimising the central banks loss function. The welfare loss at time t is the expected sum of discounted periodic losses

$$W_t \equiv E_t \left[\sum_{t=0}^{\infty} \beta^t L_t \right]. \quad (2.28)$$

The periodic loss function is the weighted sum of squared output and inflation deviations

$$L_t = \frac{1}{2} \left[(\pi_t - \pi^*)^2 + \chi (\ln y_t - \ln y_t^*)^2 \right], \quad (2.29)$$

where π^* is the inflation target, χ positive parameter reflecting the relative concern of the central bank for output stability, and $\ln y_t^* = \frac{\sigma_{\bar{z}}}{\kappa} \ln g_t + \frac{1+\lambda}{\kappa} \alpha * Time + \varepsilon_t^{y^*}$ is the desired level of potential output for the central bank (see Appendix A). The central bank targets the efficient level of output in the absence of monopolistic distortion. Also the nondistorted flexible price output does not depend on the households' labour supply decisions. Rotemberg and Woodford (1998) have shown that the loss measure can be derived by approximating the expected utility of a representative household when $\chi > 0$. As proved in Aoki and Nikolov (2003), the analysis is valid for arbitrary values of χ .

In the discretionary case, the central bank minimises the discounted losses (2.28) subject to the Phillips curve (2.24). Substituting the Phillips curve into the central bank's objective, yields a multiperiodic problem⁹

$$\min_{\{\pi_t, i=0,1,2,\dots\}} E_t \sum_{t=0}^{\infty} \beta^t \left\{ \left[\frac{1}{2} (\pi_t - \pi^*)^2 + \chi \left(\ln y_t^f - \ln y_t^* + \frac{1}{a\kappa} (\pi_t - \beta E_t \pi_{t+1}) \right)^2 \right] \right\}. \quad (2.30)$$

Under discretion, once expectations of future inflation $E_t \pi_{t+1}$ are formed, the central bank optimises, taking them as given. Hence we obtain a sequence of static minimisation problems, (see eg Cukierman 1992, Chapter 3). Optimal monetary policy under discretion is

$$\pi_t = \pi^* - \frac{\chi}{a\kappa} \left(\pi_t - \beta E_t \pi_{t+1} + a\kappa \left(\ln y_t^f - \ln y_t^* \right) \right). \quad (2.31)$$

⁹Under discretion, once expectations of future inflation $E_t \pi_{t+1}$ are formed, the central bank reoptimises taking them as given. Hence we can treat the mimimisation problem in isolation for period t . See Chapter 3 in Cukierman(1992).

As a result, a central bank that puts any emphasis on output creates an inflationary bias in the economy. Cukierman (1992) recalls the point made by Barro and Gordon (1983): under discretion, the inflationary bias of monetary policy carries over to the case in which the central bank cares the future as well as about the present. Also, the output gap is replaced by the welfare gap¹⁰. Using (2.22) and (A.6) we rewrite $\ln y_t^f - \ln y_t^* = \frac{1}{\kappa} \ln(1 - \tau_t)$. Substituting this into the optimal policy function (2.31) and rearranging yields

$$\pi_t = \frac{a\kappa}{a\kappa + \chi} \pi^* + \frac{\chi\beta}{a\kappa + \chi} E_t \pi_{t+1} - \frac{\chi a}{a\kappa + \chi} \ln(1 - \tau_t). \quad (2.32)$$

Under commitment, the central bank does not take expectations of future inflation as given. Again, the central bank minimises the loss function (2.28) subject to the Phillips curve (2.24). Using the Woodford (1999) approach, we write a Lagrangian for this problem:

$$\begin{aligned} \mathcal{L} = E_t \sum_{i=0}^{\infty} \beta^i & \left\{ \frac{1}{2} (\pi_{t+i} - \pi^*)^2 + \frac{\chi}{2} (\ln y_{t+i} - \ln y_{t+i}^*)^2 \right. \\ & \left. + \varphi_{t+i} \left[\pi_{t+i} - \beta \pi_{t+i+1} - a\kappa (\ln y_{t+i} - \ln y_{t+i}^f) \right] \right\}, \end{aligned} \quad (2.33)$$

where φ_{t+i} is a Lagrangian multiplier. The first-order conditions are

$$E_t [\pi_{t+i} - \pi^* + \varphi_{t+i} - \varphi_{t+i-1}] = 0, \quad (2.34)$$

$$E_t \left[(\ln y_{t+i} - \ln y_{t+i}^*) - \frac{a\kappa}{\chi} \varphi_{t+i} \right] = 0. \quad (2.35)$$

Using these, we substitute for π_{t+i} and $\ln y_{t+i}$ in the Phillips curve (2.24) and obtain a difference equation for the evolution of the multiplier:

$$\left[1 + \beta + \frac{(a\kappa)^2}{\chi} \right] \varphi_t - \beta E_t \varphi_{t+1} - \varphi_{t-1} = (1 - \beta) \pi^* + a\kappa (\ln y_t^f - \ln y_t^*). \quad (2.36)$$

We use equation (2.36) to solve for φ_t and φ_{t-1} in the case of the optimal commitment plan implemented since $t - 1$. A once-for-all commitment from period t would stipulate the initial condition $\varphi_{t-1} = 0$, implying that the bank exploits expectations existing at the time

¹⁰The output gap is the difference between actual and potential output, $\ln y_t - \ln y_t^f$. The welfare gap is defined to be the difference of potential output and undistorted output, which the central bank desires, $\ln y_t^f - \ln y_t^*$.

the policy is chosen. Optimality from a timeless perspective imposes a restriction on the initial evolution of endogenous variables in such a way that the bank does not exploit expectations existing at the time the policy is chosen. Like Aoki and Nikolov (2003), we impose the initial condition based on equation (2.36). See Woodford (2003, Chapter 7) for a discussion of timeless optimal plans.

Using the first-order condition (2.34), we form the linear combination

$$\begin{aligned} & \left[1 + \beta + \frac{(a\kappa)^2}{\chi} \right] \pi_t - \beta E_t \pi_{t+1} - \pi_{t-1} & (2.37) \\ = & - \left[1 + \beta + \frac{(a\kappa)^2}{\chi} \right] (\varphi_t - \varphi_{t-1}) + \beta (E_t \varphi_{t+1} - \varphi_t) \\ & + (\varphi_{t-1} - \varphi_{t-2}) + \left[\frac{(a\kappa)^2}{\chi} \right] \pi^*. \end{aligned}$$

Combining equations (2.37) and the solutions for φ_t and φ_{t-1} from (2.36), we obtain the optimal monetary policy under commitment:

$$\begin{aligned} & \left[1 + \beta + \frac{(a\kappa)^2}{\chi} \right] \pi_t = \frac{(a\kappa)^2}{\chi} \pi^* + \beta E_t \pi_{t+1} + \pi_{t-1} & (2.38) \\ & - a\kappa \left[\left(\ln y_t^f - \ln y_t^* \right) - \left(\ln y_{t-1}^f - \ln y_{t-1}^* \right) \right]. \end{aligned}$$

Using $\ln y_t^f - \ln y_t^* = \frac{1}{\kappa} \ln(1 - \tau_t)$, we rewrite (2.38) as

$$\begin{aligned} & \left[1 + \beta + \frac{(a\kappa)^2}{\chi} \right] \pi_t = \frac{(a\kappa)^2}{\chi} \pi^* & (2.39) \\ & + \beta E_t \pi_{t+1} + \pi_{t-1} - a \left[\ln(1 - \tau_t) - \ln(1 - \tau_{t-1}) \right]. \end{aligned}$$

The lagged inflation term in optimal policy equations (2.38) and (2.39) makes the inflation more persistent under commitment. This is due to the substitution of welfare gap for output gap.

Fiscal policy, following Leeper (1991), is represented as a debt rule:

$$\tau_t = \tau^* + \phi \left[(b_{t-1} + m_{t-1}) / y_t - \psi \right]. \quad (2.40)$$

Here, τ^* is a positive constant representing a long-run tax rate¹¹, $b_{t-1} + m_{t-1}$ is total real government liabilities, $\psi > 0$ represents the

¹¹ τ^* is related to the long-run tax rate, since $\frac{b_{t-1} + m_{t-1}}{y_t}$ need not equal zero.

debt-to-GDP ratio target, and ϕ is the fiscal policy parameter. The higher the value ϕ , the more weight the fiscal authority places on balancing the government budget. In Chapter 2 we show that this type of fiscal policy rule results in a determinate solution with the Taylor (1993) rule for monetary policy if the inflation response is more than one-for-one for a wide range of positive fiscal policy rule parameter values.

We also explore other fiscal policy rules. The government liabilities in the fiscal policy rule (2.40) can be replaced by the government's primary deficit, in which case the fiscal policy rule is a deficit rule of the form

$$\tau_t = \tau^* + \Omega [(g_t - \tau_t y_t + R_t b_{t-1}) / y_t - \psi_2], \quad (2.41)$$

where the primary deficit is $g_t - \tau_t y_t$ and the interest payment on real debt outstanding is $R_t b_{t-1}$. This is the SGP definition of the deficit and conforms closely with the deficit based on the real government budget constraint.

An alternative to Leeper's (1991) way of writing a fiscal policy rule is to use the differenced tax rate to get smoother tax rate movements, as suggested in Barro (1979). Another debt rule can be written as

$$\tau_t = \tau_{t-1} + \phi [(b_{t-1} + m_{t-1}) - \psi_1 y_t] / y_t. \quad (2.42)$$

In Chapter 3 we show that (2.42) is not determinate for a wide range of positive values of the parameter ϕ when monetary policy is described by the Taylor (1993) rule and is active ie interest rate responses to inflation are more than one-for-one. Therefore we do not study the effects of shocks under (2.42) using the stochastic simulation procedure described below. On the other hand, the corresponding fiscal policy rule with the deficit,

$$\tau_t = \tau_{t-1} + \Omega [(g_t - \tau_t y_t + R_t b_{t-1}) - \psi_2 y_t] / y_t \quad (2.43)$$

is determinate for a wide range of values of the fiscal policy parameter, Ω , as shown in Chapter 3 and hence will be used in the simulations.

These rules are chosen for computational convenience. We have used these rules in previous chapters, and so their stability properties are known. See Chapter 3 for a discussion of the timing of the deficit in the rule.

3 Stochastic simulation

We analyse time-series properties of inflation, interest rate, output, debt-to-GDP ratio and tax rate as responses to fundamental stochastic shocks. The stochastic nature of exogenous variables is given by (2.3) and (2.27). We also describe these relationships in the steady state. Our simulation procedure involves the model given by equations (2.16), (2.17), (2.22), (2.24), (2.25) and (A.6). Monetary policy is either discretionary (2.32) or follows the commitment solution (2.38). Fiscal policy is conducted with different policy rules: (2.40), (2.41) or (2.43). The initial and terminal values are set equal to the model's steady state values.

There are eight possible combinations for monetary and fiscal policy; we discuss five of them. We study discretionary monetary policy (2.32) with debt rule (2.40) and two deficit rules (2.41) and (2.43). The latter is written in difference form in order to get smoother tax rate responses. We also run through the monetary policy commitment solution (2.38) with debt rule (2.40) and the tax rate in difference form deficit rule (2.43). The other three cases result in indeterminacy. Not all parameter value combinations in the cases we examine are significant. Since there is no upper bound on government debt, some parameter combinations result in debt-to-GDP ratios which are quite unrealistic. We implicitly assume that there is no limit on household demand for government bonds.

We solve the model 2500 times to obtain a set of time series, which are then used to compute variability and persistence statistics. In our procedure, simulations are done in a recursive manner. In the first round the model is simulated for 2500 periods, in the second round for 2499 periods, etc. In each round, the current period shocks ν and ε^g are drawn from $N(0, \sigma_\nu^2)$ and $N(0, \sigma_{\varepsilon^g}^2)$ distributions, but for subsequent periods their values are set at zero. We set $\sigma_\nu^2 = 0.01$ and $\sigma_{\varepsilon^g}^2$ at 1% of GDP.

Following Cooley and Prescott (1995), we set $\rho = 0.81$, which means that 95% of the technology shock remains after one quarter. We set $\rho^g = 0.975$ according to Blanchard and Perotti (2002), which means that 95% of the government spending shock remains after 2 years. The model is calibrated to reflect the economic structure of a large economy. The key parameter values of the model are given in Table 1.

Table 2 shows the steady state results with debt rule (2.40) and discretionary monetary policy (2.32). We let the fiscal policy rule

Table 1: The parameter values used and not altered in simulation

σ	λ	a	Γ	δ	β
0.157	1.433	0.003	0.7	0.97	0.97
π^*	τ^*	ζ	χ	$\frac{g}{y}$	
0.02	0.24	0.018	0.05	0.4	

parameter ϕ vary from 0.1 to 1.5 and the debt-to-GDP ratio target ψ_1 from tight target (0) to loose target (1.5). As concluded in Chapters 2 and 3, low values for the fiscal policy rule parameter indicate active fiscal policy and high values indicate passive policy. As defined in Leeper (1991), the passive fiscal policy authority must generate sufficient tax revenue to balance the budget regardless of inflation, whereas the active authority is not constrained by budgetary conditions. The steady state values of tax rules (2.40) and (2.41) depend respectively on values of the fiscal policy parameters ϕ and Ω and on the values of the targets, ψ_1 and ψ_2 . However, the steady state values of tax rules (2.42) and (2.43) do not depend on values of fiscal policy parameters ϕ and Ω , but only on values of the targets, ψ_1 and ψ_2 .

We see from Table 2 that there is inflation bias with discretionary monetary policy, as inflation is above the target value, at $\pi^* = 0.02$. We also see that the size of the bias depends on the value of the fiscal policy parameter ϕ and the debt-to-GDP target, ψ_1 . The lower debt-to-GDP target implies a higher steady state debt-to-GDP ratio and higher inflation in the steady state. High tax rate is associated with a high debt-to-GDP ratio, which feeds into inflation. The debt-to-GDP ratio decreases as the values of the fiscal policy parameter increases. The largest changes in steady state values occur when the fiscal policy parameter ϕ changes from 0.1 to 0.5. This indicates that there is non-linearity in the parameter combinations.

With higher values of ϕ , changes in steady state values of inflation, tax rate and interest rate are small compared to the changes in debt-to-GDP ratio. Also, with the $\phi = 0.1$, changes in the target parameter have their largest impacts on steady state inflation and the tax rate. Notably, the debt-to-GDP ratio gets unrealistically high values due to the fact that no restrictions were put on one-period government debt issuance. This also implies that not all the parameter value combinations are reasonable. Also, the steady state tax rate is affected by the ratio of the two fiscal policy parameters in the case of the simple debt rule, but the ratio does not affect steady

Table 2: Discretionary monetary policy with the debt rule

	ϕ	0.1	0.5	1.5
	ψ_1	<i>mean</i>	<i>mean</i>	<i>mean</i>
Inflation	0	5.1	4.9	4.9
	0.6	5.8	5.1	4.9
	1.5	7.1	5.3	5.0
Interest rate	0	8.6	8.4	8.4
	0.6	9.3	8.6	8.4
	1.5	10.6	8.8	8.5
Debt-to-GDP ratio	0	155.5	20.3	-0.7
	0.6	818.1	145.5	40.6
	1.5	1812.2	333.2	102.6
Tax rate	0	40.2	39.3	39.2
	0.6	44.6	40.1	39.4
	1.5	51.3	41.4	39.8

state values in the case of the differenced tax rate. This raises the question of the role and value of the long run tax rate τ^* . We did not perform any sensitivity analysis on τ^* .

Table 3 gives the steady state ratios with the deficit rule (2.41). Here, the deficit-to-GDP target ψ_2 gets values between zero and 0.1 while the fiscal policy rule parameter Ω runs from 0.1 to 1.5. Again, we see that increasing the target raises the debt-to-GDP ratio, which impacts inflation. High debt levels are associated with high tax rates and low fiscal policy parameter values. Overall, the debt and deficit rules result in similar steady state values as fiscal policy parameter and target values change.

Table 4 shows the steady state values under the deficit rule (2.43). Here, the fiscal policy parameter Ω does not affect the steady state tax rate or steady state debt-to-GDP ratio. Increase in the deficit target ψ_2 raises the steady state debt-to-GDP ratio and inflation. However, changing the deficit target has only a small effect on the level of steady state inflation compared to its quite large impact on the debt-to-GDP ratio. Note that the ratio of fiscal policy parameters does not affect the steady state debt-to-GDP ratio when the fiscal policy rule is written in the difference form.

Tables 5 and 6 display the steady state values when the monetary policy authority is able to commit. As expected, inflation is on target for all combinations of fiscal policy parameter and target values. With the debt rule (2.40), the debt-to-GDP ratio increases as the fiscal

Table 3: Discretionary monetary policy with the deficit rule

	Ω	0.1	0.5	1.5
	ψ_2	<i>mean</i>	<i>mean</i>	<i>mean</i>
Inflation	0	9.0	5.4	5.1
	0.03	9.5	5.5	5.1
	0.1	10.6	5.7	5.2
Interest rate	0	12.5	8.9	8.5
	0.03	13.0	9.0	8.6
	0.1	14.0	9.2	8.6
Debt-to-GDP ratio	0	3120.0	443.8	128.9
	0.03	3408.4	529.8	156.1
	0.1	3976.3	712.5	218.7
Tax rate	0	60.0	42.1	40.0
	0.03	61.9	42.7	40.2
	0.1	65.7	43.9	40.6

Table 4: Discretionary monetary policy with deficit rule in difference form

	Ω	0.1	0.5	1.5
	ψ_2	<i>mean</i>	<i>mean</i>	<i>mean</i>
Inflation	0	4.9	4.9	4.9
	0.03	5.0	5.0	5.0
	0.1	5.0	5.0	5.0
Interest rate	0	8.4	8.4	8.4
	0.03	8.4	8.4	8.4
	0.1	8.5	8.5	8.5
Debt-to-GDP ratio	0	-11.1	-11.1	-11.1
	0.03	28.8	28.8	28.8
	0.1	120.1	120.1	120.1
Tax rate	0	39.1	39.1	39.1
	0.03	39.4	39.4	39.4
	0.1	40.0	40.0	40.0

Table 5: Committed monetary policy with the debt rule

	ϕ	0.1	0.5	1.5
	ψ_1	<i>mean</i>	<i>mean</i>	<i>mean</i>
Inflation	0	2.0	2.0	2.0
	0.6	2.0	2.0	2.0
	1.5	2.0	2.0	2.0
Interest rate	0	5.5	5.5	5.5
	0.6	5.5	5.5	5.5
	1.5	5.5	5.5	5.5
Debt-to-GDP ratio	0	155.4	18.5	-2.9
	0.6	817.9	143.5	38.4
	1.5	1811.6	331.1	100.4
Tax rate	0	40.4	39.5	39.4
	0.6	44.9	40.3	39.6
	1.5	51.6	41.6	40.1

policy parameter ϕ value decreases and the debt-to-GDP target ψ_1 increases. The change in monetary policy regime did not change the extremely high steady state debt-to-GDP ratio, with low ϕ and high ψ_1 values, from those for the discretionary case.

With the difference-form deficit rule (2.43), the fiscal policy parameter does not affect on steady state debt-to-GDP ratios. However, the debt-to-GDP ratio increases as the deficit target increases, which results in a higher steady state tax rate.

Tables 7 to 11 display the variability and persistence statistics as responses to the underlying fundamental stochastic shocks. We let the fiscal policy parameters, ϕ and Ω , run from 0.1 to 1.5 and the target parameter value from low (tight) to higher values (looser).

Barro (1979) claims that an optimal monetary and fiscal policy results in an optimal tax rate and debt follows a random walk. Lucas and Stokey (1983) and Chari et al (1991 and 1994) show that with flexible prices Barro's result that an optimal tax rate follows a random walk does not hold. Chari et al (1991 and 1994) also claim that the tax rate and debt inherit the serial correlation of the model's underlying shocks. Siu (2004) found that in a sticky price model, especially in the case where the government has accumulated debt, finances spending by increasing taxes, the autocorrelation between debt-to-GDP ratio and tax rate is close to unity, regardless of persistence in the shock process. This partially revives Barro's random walk result.

Table 6: Committed monetary policy with deficit rule in difference form

	Ω	0.1	0.5	1.5
	ψ_2	<i>mean</i>	<i>mean</i>	<i>mean</i>
Inflation	0	2.0	2.0	2.0
	0.03	2.0	2.0	2.0
	0.1	2.0	2.0	2.0
Interest rate	0	5.5	5.5	5.5
	0.03	5.5	5.5	5.5
	0.1	5.5	5.5	5.5
Debt-to-GDP ratio	0	-13.4	-13.4	-13.4
	0.03	51.0	51.0	51.0
	0.1	201.3	201.3	201.3
Tax rate	0	39.3	39.3	39.3
	0.03	39.7	39.7	39.7
	0.1	40.7	40.7	40.7

Table 7 shows that the variability of inflation decreases as the parameter ϕ in the debt rule (2.40) increases in value, but the variability of the tax rate increases. The variability of both inflation and tax rate increases as the debt-to-GDP target, ψ_1 , gets larger values. Inflation and the interest rate are highly autocorrelated for all parameter values. The persistence of the debt-to-GDP ratio and tax rate decreases or either the fiscal policy parameter or the debt-to-GDP target (or both) get larger values. With low target values, ie a low steady state debt-to-GDP ratio, the autocorrelation of debt-to-GDP and tax rate are close to unity, giving support to Barro's (1979) result. However, increasing the target values, ie making the debt-to-GDP ratio less restrictive, reduces the autocorrelation of the variables and supports the Chari et al (1991 and 1994) result, even in a sticky price model. Output variability and persistence remain quite constant and low regardless of changes in the parameter values.

Table 8 repeats the previous results, now with the deficit rule (2.41). The overall results are similar to the previous results, but the persistence of debt-to-GDP and tax rate do not decrease with increases in the values of the Ω and ψ_2 parameters. Here, we find support for Barro (1979) and Siu (2004) with all parameter value combinations. The changes in fiscal policy do not affect the persistence of the tax rate. However, output persistence and volatility do not improve due to the results with the debt rule.

The introduction of differences in the tax rate for the deficit rule (2.43) does not change the results significantly compared with the deficit rule (2.41), as can be seen from Table 9. Persistence remains high for inflation, interest rate, debt-to-GDP ratio and the tax rate. However, the variability of inflation decreases with low fiscal policy parameter Ω values compared with the results for the deficit rule. This is due to the fact that the fiscal policy parameter has no impact on the debt-to-GDP ratio and hence none on the level of inflation, with the deficit rule (2.43). The variability of the debt-to-GDP ratio is smaller when the level of the debt-to-GDP is smaller.

Table 10 shows the results with committed monetary policy (2.38) and debt rule (2.40). Note that under monetary policy commitment output persistence increases significantly compared to the discretionary case, as the optimal monetary policy under commitment (2.39) displays a lagged inflation term. The lagged inflation term comes from the optimality in the timeless perspective approach with welfare gap instead of output gap. As persistence increases, there is a considerable increase in the variability of output. Whereas the variability of output increases under commitment, that of inflation and interest rate decreases. The variability of tax rate and debt-to-GDP ratio remains quite similar for discretionary versus committed monetary policy. However, the persistence of both increases somewhat, especially with high fiscal policy and debt-to-GDP target values. Still, the autocorrelation between the two variables supports Barro's finding when the target has low values. As the debt-to-GDP ratio increases and fiscal policy reacts more via taxes, the autocorrelation decreases and the tax rate inherits the serial correlation of the shock, as in Chari et al (1991 and 1994).

The same result obtains with the deficit rule (2.43). The results in Table 11 are similar to those of discretionary monetary policy with the deficit rule, except for output. As in the previous case, the volatility and persistence of output increase significantly compared to the discretionary monetary policy case. The autocorrelations of debt-to-GDP and tax rate remain high, reflecting Barro's results, for all fiscal parameter combinations.

4 Conclusions

In this chapter we analysed the effects of alternative fiscal policy rules with optimal monetary policy. With discretionary monetary policy, inflation bias depends on fiscal policy, with both debt and deficit rules. The fiscal policy parameter and target values, and hence the fiscal policy regime, affect the size of the bias. The larger the values of the fiscal policy parameter and target parameter, the higher the steady state debt-to-GDP ratio and inflation rate. Change in the target parameter increase inflation more evenly, but policy parameter changes are greater with low values than with high values.

With the deficit rule and tax rate in difference form, the fiscal policy parameter has no impact on the steady state tax rate nor on the steady state debt-to-GDP level. An increase in the deficit target raises the steady state debt-to-GDP ratio and inflation. However, changing the deficit target has a small effect on the level of steady state inflation compared to the fairly large impact on debt-to-GDP ratio.

The stochastic simulation results show that under central bank commitment output persistence increases compared to the discretionary case. This result is derived using the timeless perspective approach to precommitment. Here, inflation and output persistence increase, reflecting the economic data. However, the variability of output increases compared to the discretionary case. Fiscal policy is also compatible with the commitment to optimal monetary policy and the previous result also holds with alternative fiscal policy rules. The fiscal policy parameter and target values do not affect the persistence of inflation and output.

With the deficit rules, the autocorrelation of the tax rate is close to unity, irrespective of monetary policy regime and of fiscal policy parameters and targets. Thus we find support for Barro's (1979) random walk result with the deficit rules. The tax rate changes are smooth, as autocorrelation is close to unity for all combinations of fiscal policy parameter and deficit-to-GDP target, with the fiscal policy rules formulated as differences in tax rate. With the debt rules and high debt-to-GDP target values, the Barro result does not hold and the tax rate inherits the stochastic nature of underlying shocks, also in a sticky price model.

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A Appendix A: Potential output without distortionary taxes

We rewrite the household's budget constraint with lump sum taxation as

$$c_t + m_t - (1 - \pi_t)m_{t-1} + b_t \leq (1 + r_{t-1})b_{t-1} + w_t l_t - T_t, \quad (\text{A.1})$$

where T_t is lump sum taxes. Now the household's utility maximisation using the periodic utility function $u(c_t, m_t, l_t; g_t) = \frac{c_t^{1-\sigma}}{1-\sigma} + \frac{\Gamma m_t^{1-\sigma}}{1-\sigma} - \frac{l_t^{1+\lambda}}{1+\lambda} + f(g_t)$ yields a first-order condition for labour supply:

$$-l_t^\lambda = -[c_t^{-\sigma} w_t]. \quad (\text{A.2})$$

The real marginal cost to the cost minimising firm is

$$\frac{\partial}{\partial y_t} \left[w_t \left(\frac{y_t}{A} \right) \right] = w_t \frac{1}{A} = mc_t. \quad (\text{A.3})$$

With equilibrium wages $w_t = c_t^\sigma \left(\frac{y_t}{A} \right)^\lambda$, the real marginal cost is

$$c_t^\sigma y_t^\lambda A^{-(1+\lambda)} = mc_t. \quad (\text{A.4})$$

In order to log-linearise (A.4), first substitute in the process for technological progress $A = \zeta_t e^{\alpha * Time}$ and take natural logarithms. Substitute the definition $\hat{x}_t = \ln(x_t/\bar{x})$ into the resource constraint $\hat{c}_t = \frac{\bar{y}}{\bar{c}} \hat{y}_t - \frac{\bar{g}}{\bar{c}} \hat{g}_t$ to yield

$$\left(\sigma \frac{\bar{y}}{\bar{c}} + \lambda \right) \hat{y}_t - \sigma \frac{\bar{g}}{\bar{c}} \hat{g}_t - (1 + \lambda) \hat{\zeta}_t = \widehat{mc}_t. \quad (\text{A.5})$$

In a flexible price equilibrium, the long-run supply function can be written

$$\ln y_t^* = \frac{\sigma \bar{g}}{\kappa} \ln g_t + \frac{1 + \lambda}{\kappa} \alpha * Time + \varepsilon_t^{y^*}, \quad (\text{A.6})$$

where y_t^* is the level of flexible price output, which is the desired level of output for the central bank, $\kappa = \left(\sigma \frac{\bar{y}}{\bar{c}} + \lambda \right)$ and $\varepsilon_t^{y^*} = \frac{1+\lambda}{\kappa} z_t$.¹² As we can see from (2.22) and (A.6), the long-run flexible price output and desired level of output are both affected by the same technology shock (2.3).

¹²Note that $z_t \equiv \ln \zeta_t$.

Table 7: Discretionary monetary policy with the debt rule

	ϕ	0.1	0.5	1.5
	ψ_1	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)
Inflation	0	0.5047	0.4514	0.4226
	—	(0.9878)	(0.9782)	(0.9741)
	0.6	0.5553	0.4026	0.4573
	—	(0.9887)	(0.9756)	(0.9790)
	1.5	0.6715	0.4506	0.4069
	—	(0.9902)	(0.9807)	(0.9731)
Interest rate	0	0.5289	0.4514	0.4226
	—	(0.9793)	(0.9726)	(0.9652)
	0.6	0.5762	0.4221	0.4804
	—	(0.9807)	(0.9665)	(0.9683)
	1.5	0.6952	0.4714	0.4262
	—	(0.9818)	(0.9724)	(0.9667)
Output	0	1.6657	1.7173	1.6850
	—	(0.1875)	(0.1914)	(0.1593)
	0.6	1.6875	1.6535	1.7114
	—	(0.1221)	(0.1675)	(0.2262)
	1.5	1.6886	1.6862	1.6436
	—	(0.1729)	(0.1662)	(0.1647)
Debt-to-GDP ratio	0	45.560	10.809	4.3282
	—	(0.9959)	(0.9904)	(0.9465)
	0.6	45.808	9.5861	4.8640
	—	(0.9240)	(0.9662)	(0.9234)
	1.5	54.799	10.767	4.4393
	—	(0.7774)	(0.8929)	(0.7539)
Tax rate	0	4.3275	4.6883	4.6699
	—	(0.9950)	(0.9870)	(0.9147)
	0.6	4.4212	4.3136	5.5601
	—	(0.9022)	(0.8768)	(0.6704)
	1.5	5.4342	5.3802	6.5240
	—	(0.7192)	(0.6182)	(0.0470)

Note: corr. is the first-order autocorrelation coefficient.

Table 8: Discretionary monetary policy with the deficit rule

	Ω	0.1	0.5	1.5
	ψ_2	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)
Inflation	0	0.7794	0.5291	0.4229
	—	(0.9932)	(0.9894)	(0.9785)
	0.03	0.8580	0.5289	0.3901
	—	(0.9910)	(0.9888)	(0.9762)
	0.1	0.8019	0.5130	0.3927
	—	(0.9834)	(0.9877)	(0.9753)
Interest rate	0	0.8012	0.5523	0.4423
	—	(0.9870)	(0.9817)	(0.9708)
	0.03	0.8773	0.5535	0.4097
	—	(0.9848)	(0.9823)	(0.9660)
	0.1	0.8196	0.5366	0.4132
	—	(0.9752)	(0.9810)	(0.9594)
Output	0	1.6827	1.7118	1.6302
	—	(0.1909)	(0.1533)	(0.1341)
	0.03	1.6832	1.6855	1.6675
	—	(0.1423)	(0.2103)	(0.1663)
	0.1	1.6987	1.6764	1.6796
	—	(0.1523)	(0.2090)	(0.1312)
Debt to GDP ratio	0	148.53	74.916	24.766
	—	(0.9073)	(0.9898)	(0.9915)
	0.03	114.93	64.706	22.272
	—	(0.7975)	(0.9850)	(0.9867)
	0.1	84.717	62.420	19.857
	—	(0.5051)	(0.9720)	(0.9680)
Tax rate	0	3.8454	4.2277	3.9187
	—	(0.9658)	(0.9900)	(0.9844)
	0.03	4.0399	4.0738	3.6504
	—	(0.9497)	(0.9882)	(0.9818)
	0.1	3.7197	4.2073	3.7104
	—	(0.9007)	(0.9836)	(0.9778)

Note: corr. is the first-order autocorrelation coefficient.

Table 9: Discretionary monetary policy with deficit rule in difference form

	Ω	0.1	0.5	1.5
	ψ_2	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)
Inflation	0	0.4674	0.4140	0.4782
	—	(0.9808)	(0.9735)	(0.9802)
	0.03	0.4251	0.3737	0.4281
	—	(0.9774)	(0.9679)	(0.9750)
	0.1	0.4796	0.4303	0.4069
	—	(0.9805)	(0.9734)	(0.9709)
Interest rate	0	0.4867	0.4326	0.4982
	—	(0.9751)	(0.9678)	(0.9755)
	0.03	0.4472	0.3915	0.4487
	—	(0.9568)	(0.9599)	(0.9683)
	0.1	0.5036	0.4482	0.4271
	—	(0.9623)	(0.9661)	(0.9585)
Output	0	1.6460	1.6394	1.7167
	—	(0.1589)	(0.1340)	(0.2000)
	0.03	1.6747	1.6865	1.7191
	—	(0.1082)	(0.1575)	(0.1870)
	0.1	1.6737	1.7057	1.6883
	—	(0.2108)	(0.1813)	(0.1696)
Debt-to-GDP ratio	0	22.773	4.9277	2.3736
	—	(0.9937)	(0.9756)	(0.9583)
	0.03	22.228	4.8715	2.1743
	—	(0.9934)	(0.9602)	(0.8753)
	0.1	24.924	7.0619	5.4831
	—	(0.9896)	(0.9117)	(0.8614)
Tax rate	0	4.7344	4.3898	5.2316
	—	(0.9980)	(0.9947)	(0.9924)
	0.03	4.3486	4.1160	4.8055
	—	(0.9964)	(0.9933)	(0.9894)
	0.1	5.1300	4.7837	4.5675
	—	(0.9969)	(0.9936)	(0.9858)

Note: corr. is the first-order autocorrelation coefficient.

Table 10: Committed monetary policy with the debt rule

	ϕ	0.1	0.5	1.5
	ψ_1	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)
Inflation	0	0.3780	0.2664	0.4088
	—	(0.9993)	(0.9989)	(0.9994)
	0.6	0.3780	0.4790	0.2716
	—	(0.9993)	(0.9994)	(0.9980)
	1.5	1.1061	0.3506	0.4772
	—	(0.9993)	(0.9980)	(0.9981)
Interest rate	0	0.3762	0.2655	0.3914
	—	(0.9712)	(0.9505)	(0.9810)
	0.6	0.3762	0.4619	0.2649
	—	(0.9891)	(0.9789)	(0.9685)
	1.5	1.0428	0.3385	0.4595
	—	(0.9957)	(0.9804)	(0.9862)
Output	0	5.3338	3.7499	5.6589
	—	(0.9300)	(0.8590)	(0.9373)
	0.6	5.3338	6.1079	3.9712
	—	(0.9354)	(0.9473)	(0.8751)
	1.5	9.2104	4.7310	6.0799
	—	(0.9470)	(0.8995)	(0.9433)
Debt to GDP ratio	0	55.867	8.8037	4.8565
	—	(0.9967)	(0.9853)	(0.9607)
	0.6	51.656	11.2068	3.9692
	—	(0.9381)	(0.9704)	(0.9080)
	1.5	79.207	10.593	4.6603
	—	(0.7823)	(0.8837)	(0.8086)
Tax rate	0	5.3254	3.8769	5.4925
	—	(0.9965)	(0.9852)	(0.9490)
	0.6	4.9912	5.1570	4.8087
	—	(0.9251)	(0.9201)	(0.6558)
	1.5	8.0805	5.3370	6.9800
	—	(0.7601)	(0.6447)	(0.2226)

Note: corr. is the first-order autocorrelation coefficient.

Table 11: Committed monetary policy with deficit rule in difference form

	Ω	0.1	0.5	1.5
	ψ_2	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)	<i>std</i> (<i>corr.</i>)
Inflation	0	0.4174	0.4230	0.3468
	—	(0.9994)	(0.9995)	(0.9994)
	0.03	0.3110	0.4737	0.3328
	—	(0.9988)	(0.9996)	(0.9993)
	0.1	0.3112	0.2766	0.4017
	—	(0.9989)	(0.9988)	(0.9994)
Interest rate	0	0.4103	0.4106	0.3340
	—	(0.9767)	(0.9759)	(0.9745)
	0.03	0.3134	0.4595	0.3223
	—	(0.9678)	(0.9714)	(0.9733)
	0.1	0.3124	0.2741	0.3907
	—	(0.9628)	(0.9483)	(0.9627)
Output	0	5.0627	5.2468	4.7477
	—	(0.9248)	(0.9274)	(0.9169)
	0.03	3.6744	5.8583	4.6473
	—	(0.8536)	(0.9439)	(0.9074)
	0.1	4.0660	4.3010	5.5021
	—	(0.8660)	(0.8868)	(0.9225)
Debt-to-GDP ratio	0	27.826	6.2676	2.4566
	—	(0.9959)	(0.9833)	(0.9615)
	0.03	27.942	9.7789	5.0680
	—	(0.9941)	(0.9776)	(0.9505)
	0.1	27.762	13.558	13.401
	—	(0.9826)	(0.9348)	(0.9622)
Tax rate	0	4.5000	4.7386	4.2570
	—	(0.9985)	(0.9949)	(0.9876)
	0.03	4.6680	4.9807	4.5649
	—	(0.9979)	(0.9950)	(0.9887)
	0.1	4.2214	5.0815	4.9495
	—	(0.9979)	(0.9943)	(0.9891)

Note: corr. is the first-order autocorrelation coefficient.

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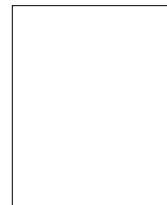
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