Monetary and Fiscal Policy Interactions without Commitment

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Abstract

We study dynamic monetary and fiscal policy games in a sticky price economy where a monetary authority sets nominal interest rates and a fiscal authority determines the level of public goods provision. We compare the Ramsey outcome to non-cooperative policy regimes where one or both policymakers lack commitment power. The welfare costs of sequential fiscal spending policy are found to be relatively small. Sequential monetary policy instead leads to significant welfare losses by generating an inflation bias and a government spending bias, independently of whether or not fiscal policy can commit. Impulse responses to technology shocks are surprisingly robust across the considered policy regimes. The response to preference shocks, however, is sensitive to whether or not there is monetary commitment. Making the monetary authority appropriately conservative eliminates the steady state distortions associated with sequential monetary policy, but also almost fully eliminates those generated by sequential fiscal spending policy.

Keywords: dynamic games, optimal monetary and fiscal policy, lack of commitment, sequential policy, discretionary policy

JEL Class.-No.: E52, E62, E63

1 Motivation

The aim of this paper is to analyze the interaction between monetary and fiscal stabilization policies in a setting where some or all policymakers cannot commit to future policy choices.

The difficulties associated with executing optimal but time-inconsistent policy plans have received much attention following the work of Kydland and Prescott (1977) and Barro and Gordon (1983). Time inconsistency problems,

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however, have hardly been analyzed in a setting where monetary and fiscal policymakers are separate authorities engaged in a non-cooperative dynamic policy game. This may appear somewhat surprising given that the institutional setup in most developed countries suggests such an analysis, as here carried out, to be of relevance.

Presented is a dynamic sticky price economy without capital along the lines of Rotemberg (1982) and Woodford (2003) where output is inefficiently low due to market power by firms. The economy features two independent policymakers, i.e., a fiscal authority deciding about the level of public goods provision and a monetary authority determining the short-term nominal interest rate. Public goods generate utility for private agents and are financed by lump sum taxation. Monetary and fiscal authorities are both benevolent and maximize the utility of the representative agent.

The natural starting point of our analysis is the Ramsey allocation, which assumes full policy commitment and cooperation among monetary and fiscal policymakers. The Ramsey allocation is second-best, it thus provides a useful benchmark against which one can assess the welfare costs of sequential and non-cooperative policymaking.

Analyzing sequential policy is of interest because both monetary and fiscal authorities face a time-inconsistency problem. Since private agents are forward-looking, policymakers that decide sequentially fail to perceive the implications of their current actions on past expectations and past decisions of private agents. As a result, the costs of policy decisions are not fully internalized, this generates an incentive to increase output above its second-best level. Sequential monetary policy, e.g., seeks to generate 'surprise' inflation because it fails to take into account the inflation expectations generated by its policy. This results in the familiar 'inflation bias'. Similarly, sequential fiscal policy engages in excessive spending on public goods, leading to a public spending bias.

We first consider the situation where one policymaker decides sequentially while the other commits to a (contingent) policy at time zero. In such a setting, the committing authority has considerable leverage over the sequential authority. In particular, if the sequential policymaker rationally anticipates the behavior of the committing one, then the latter can induce any behavior of the sequential authority by threatening to implement appropriate punishments in case of deviations. Crucially, such threats are costless for the committing authority because they never have to be actually implemented in equilibrium. As a result, whenever at least one authority can credibly commit the Ramsey allocation is the unique outcome of the Nash policy game.

The problem is more interesting if there is a limit to the power of the committing player. We apply the concept of a 'self-confirming equilibrium' (SCE), see Fudenberg and Levine (1993) and Sargent (1999). In a SCE the sequential decision maker holds rational beliefs about the equilibrium play, but not necessarily so about off-equilibrium play, i.e., the punishments threatened by the committing player. In particular, we consider sequential decision makers that assume the other policymaker's strategy to be independent of own past policy decisions. While this is not necessarily the case, off-equilibrium behavior is never observed so this independence assumption is never contradicted. Interestingly, in the case where both decision makers decide sequentially the self-confirming equilibrium corresponds to a Markov-perfect Nash equilibrium, i.e., a standard refinement applied in the applied dynamic games literature, e.g., Klein et al. (2004).

We first consider a policy regime with sequential fiscal policy (SFP) and monetary commitment. The steady state of the resulting self-confirming equilibrium features an increased fiscal spending on public goods, partial crowding out of private consumption and a small amount of inflation. Overall, however, we find sequential fiscal spending policy to generate only negligible steady state welfare losses. This finding seems to be robust over a range of model parametrizations.

We then consider the reverse situation with sequential monetary policy (SMP) and time zero commitment by the fiscal authority. The steady state welfare losses generated by sequential monetary policy are found to be sizable, namely two orders of magnitude larger than the ones generated in the SFP regime. Sequential monetary policy leads to the familiar inflation bias, but interestingly also induces a fiscal spending bias despite fiscal commitment.

Finally, we consider the case with both sequential monetary and fiscal policy (SMFP). This setting generates the worst equilibrium in utility terms and features an inflation bias as well as a government spending bias. The steady state welfare outcome, however, is only marginally inferior to the SMP regime.

These findings indicate that sequential monetary policy generates considerably higher steady state welfare costs relative to sequential fiscal spending on public goods. To assess the welfare consequences associated with stochastic shocks and compare these across the different policy regimes, impulse responses to technology and preference shocks are derived. Somewhat surprisingly, we find the response to technology shocks to be almost unaffected by the policy arrangement in place. The responses to a shock to the marginal utility of consumption, however, differs considerably across regimes and mainly depends on whether or not monetary policy can commit. Monetary commitment is thus confirmed again to be the main factor determining the welfare level that can be achieved by a particular policy arrangement.

We then explore if a conservative central bank that assigns a larger weight than the representative consumer to inflation deviations, as in Rogoff (1985), or a lower target value for inflation, as in Svensson (1997), would generate welfare superior equilibrium outcomes. We find both approaches to be effective in reducing the steady state distortions associated with sequential monetary policy. In a regime where fiscal policy can commit, an appropriately conservative central bank completely eliminates the steady state distortions. Furthermore, in a regime with sequential monetary and fiscal policy, a conservative central bank also almost fully eliminates the steady state distortions generated by the lack of fiscal commitment.

The remainder of this paper is structured as follows. After discussing the related literature in section 2, section 3 introduces the economic model and derives the implementability constraints. Section 4 presents the monetary and fiscal policy regimes and describes the equilibrium concept. After calibrating the model in section 5, section 6 describes the numerical approach used for solving the equilibrium dynamics. Section 7 discusses the steady state effects generated by the various policy regimes, while section 8 presents impulse responses to technology and preference shocks. The case of a conservative central bank is analyzed in section 9. A conclusion briefly summarizes the results and provides an outlook on future work to be explored. Most of the technical details are collected in an appendix.

2 Related Literature

Problems of monetary and fiscal policy are traditionally studied within the optimal taxation framework introduced by Frank Ramesy (1927). In the so-called Ramsey literature, monetary and fiscal authorities are treated as a 'single' authority and decisions are taken at time zero, e.g., Chari and Kehoe (1998). In seminal contributions, Kydland and Prescott (1977) and Barro and Gordon (1983) show that time zero optimal choices might be time-inconsistent, i.e., reoptimization in successive periods would suggest a different policy to be optimal than the one initially envisaged.

The monetary policy literature has extensively studied time-inconsistency problems in dynamic settings and potential solutions to it, e.g., Rogoff (1985), Svensson (1997), and Walsh (1995). However, in this literature fiscal policy is typically absent or assumed exogenous to the model. Similarly, a number of contributions have analyzed sequential fiscal decision making and the time-consistency of optimal fiscal plans in dynamic general equilibrium models, e.g., Lucas and Stokey (1983), Chari and Kehoe (1990), or Klein, Krusell, and Ríos-Rull (2004). This literature typically studies real models without money.

A range of papers discusses monetary and fiscal policy interactions with and without commitment in a static framework where monetary and fiscal policymakers interact only once. Alesina and Tabellini (1987), e.g., consider a model where the monetary authority chooses the inflation rate and the fiscal authority sets the tax rate to finance government expenditure. When policymakers disagree about the trade-off between output and inflation, then monetary commitment might not be welfare improving. Reduced seignorage leads to increased fiscal taxation and this might more than compensate the gains from reduced inflation.

In a series of papers Dixit and Lambertini analyze the interaction between monetary and fiscal policymakers with and without commitment. Namely, Dixit and Lambertini (2001, 2003b) analyze the case of a monetary union in a setting where for the monetary authority there isn't a time-inconsistency problem. When monetary and fiscal policymakers share the same ideal points for output and inflation, the equilibrium is second-best even if there is disagreement between the authorities regarding the relative weights attached to these objectives. However, if monetary and fiscal authorities have different bliss points, then the strategic interactions generate distortions that lead to extreme outcomes where output is above and inflation below either authority's ideal point.

Dixit and Lambertini (2003a) consider a situation where monetary and fiscal policymakers are both subject to a time-inconsistency problem. While the fiscal authority maximizes social welfare, the monetary authority has a more conservative output and inflation target and ignores the distortions generated by fiscal policy instruments. In such a setting monetary commitment is negated when fiscal policy cannot commit, i.e., the equilibrium outcome is then the same as with sequential monetary policy, provided it is implemented before fiscal policy.

The analysis in this paper goes beyond these earlier contributions by studying a stochastic, dynamic forward-looking model where current economic outcomes are influenced also by expectations about future policy.

Recently, Díaz-Giménez et al. (2004) have studied sequential monetary policy in a cash-in-advance economy with government debt. The paper focuses on the implications of indexed and nominal debt for monetary policy choices with and without commitment but also discusses interactions between monetary and fiscal policy. The setup is complementary to ours and considers a flexible-price model with exogenous government expenditure and fiscal policy that consists of determining the level of consumption taxes. The current paper considers a sticky price economy with lump sum taxes where fiscal policy consists of determining the level of government expenditures.

3 The Economy

The next sections introduce our sticky price economy model, similar to the one studied in Schmitt-Grohé and Uribe (2004), then derives the private sector equilibrium for given monetary and fiscal policy choices.

3.1 Private Sector

There is a continuum of identical households with preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, g_t, \xi_t) \tag{1}$$

where c_t denotes consumption of an aggregate consumption good, $h_t \in [0,1]$ denotes the labor supply, and g_t public good provision by the government in the form of aggregate consumption goods. The variable ξ_t denotes a stochastic preference shock. For the purpose of this paper we will assume that

$$u(c_t, h_t, g_t, \xi_t) = \frac{(\xi_t c_t)^{1-\sigma} - 1}{1-\sigma} + \omega_0 \log(1-h_t) + \omega_1 \log(g_t)$$

where $\omega_0 > 0$, $\omega_1 \geq 0$ and $\sigma > 0$.

Each household produces a differentiated intermediate good. Demand for that good is given by

$$y_t d(\frac{\widetilde{P}_t}{P_t})$$

where y_t denotes (private and public) demand for the aggregate good, $\widetilde{P}_t$ is the price of the good produced by the household, and P_t is the price of the aggregate good. The demand function $d(\cdot)$ satisfies

$$d(1) = 1$$
$$\frac{\partial d}{\partial(\widetilde{P}_t/P_t)}(1) = \eta$$

where $\eta < -1$ denotes the elasticity of substitution between the goods of different households. The household chooses $\widetilde{P}_t$ and then hires the necessary amount of labor $\widetilde{h}_t$ to satisfy the resulting product demand, i.e.,

$$z_t \widetilde{h}_t = y_t d(\frac{\widetilde{P}_t}{P_t}) \tag{2}$$

where z_t denotes an aggregate productivity shock. Following Rotemberg (1982) we describe sluggish nominal price adjustment by assuming that firms face quadratic resource costs for adjusting prices given by

$$\frac{\theta}{2}(\frac{\widetilde{P}_t}{\widetilde{P}_{t-1}} - 1)^2$$

The flow budget constraint of the household is given by

$$P_t c_t + B_t = R_{t-1} B_{t-1} + P_t \left[\frac{\widetilde{P}_t}{P_t} y_t d_t(\frac{\widetilde{P}_t}{P_t}) - w_t \widetilde{h}_t - \frac{\theta}{2}(\frac{\widetilde{P}_t}{\widetilde{P}_{t-1}} - 1)^2 \right] + P_t w_t h_t - P_t l_t \tag{3}$$

where B_t denotes nominal bonds that pay $B_t R_t$ in period $t+1$, w_t is the real wage paid on a competitive labor market, and l_t are lump sum taxes.

Although in the economy bonds are the only available financial instrument, assuming complete financial markets instead would make no difference for the analysis because households have identical incomes in a symmetric price setting equilibrium. One should note that we also abstract from money holdings. This should be interpreted as the cashless limit of an economy with money, see Woodford (1998). Money then only imposes a lower bound on the gross nominal interest rate, i.e.,

$$R_t \geq 1 \tag{4}$$

at each period. Abstracting from money entails that we ignore seignorage revenues generated from positive nominal interest rates. Given the size of these revenues in relation to GDP in industrialized economies, this does not seem to be an important omission for the analysis conducted in this paper. Moreover, assuming the existence of lump sum taxes it would be inefficient to use seignorage as a source of government revenue.

Finally, we impose a no Ponzi scheme constraint on households

$$\lim_{j\to\infty} E_t \left[\left(\prod_{i=0}^{t+j-1} \frac{1}{R_i} \right) B_{t+j} \right] \geq 0 \tag{5}$$

The household's maximization problem then consists of choosing $\{c_t, h_t, \widetilde{h}_t, \widetilde{P}_t, B_t\}_{t=0}^{\infty}$ so as to maximize (1) subject to (2), (3), and (5) taking as given $\{y_t, P_t, w_t, R_t, l_t, z_t, g_t\}$. Using equation (2) to substitute $\widetilde{h}_t$ in (3) and letting the multiplier on (3) be λ_t/P_t, the first order conditions of the household's problem are then equations (2), (3), and (5) holding with equality and

$$u_c(c_t, h_t, g_t, \xi_t) = \lambda_t$$
$$u_h(c_t, h_t, g_t, \xi_t) = -\lambda_t w_t$$
$$\lambda_t = \beta E_t \lambda_{t+1} \frac{R_t}{\Pi_{t+1}}$$

$$0 = \lambda_t \left(y_t d(r_t) + r_t y_t d'(r_t) - \frac{w_t}{z_t} y_t d'(r_t) - \theta(\Pi_t \frac{r_t}{r_{t-1}} - 1) \frac{\Pi_t}{r_{t-1}} \right) + \beta\theta E_t \left[\lambda_{t+1} (\frac{r_{t+1}}{r_t} \Pi_{t+1} - 1) \frac{r_{t+1}}{r_t^2} \Pi_{t+1} \right]$$

where

$$r_t = \frac{\widetilde{P}_t}{P_t}$$

denotes the relative price. Furthermore, there is the transversality constraint

$$\lim_{j\to\infty} E_t \left(\beta^{t+j} u_c(c_{t+j}, h_{t+j}, g_{t+j}, \xi_{t+j}) \frac{B_{t+j}}{P_{t+j}} \right) = 0 \tag{6}$$

which has to hold at all contingencies. Finally, technology and preference shocks are assumed to be described by

$$z_t = (1-\rho_z) + \rho_z z_{t-1} + \varepsilon_{z,t} \tag{7}$$

$$\xi_t = (1-\rho_\xi) + \rho_\xi \xi_{t-1} + \varepsilon_{\xi,t} \tag{8}$$

where the innovations $\varepsilon_{i,t}$ $(i = z, \xi)$ are mean zero and independent both across time and cross sectionally. We assume a small bounded support for the innovations so to insure that z_t and ξ_t both remain positive and that the lower bound (4) never binds in equilibrium.

For further reference, we let $s_t = \{\xi_t, z_t\}$ denote the current values of the preference and technology shocks and $s^t = \{s_t, s_{t-1}, \ldots, s_0\}$ summarizes the history of these shocks up to period t. More generally, we will use the notational convention that superscript indices denote the complete history of a variable while subscripts denote current period values, e.g., R_t denotes the period t value of the nominal interest rate and R^t is the history of nominal interest rate up to period t.

3.2 Government

The government consists of a monetary authority choosing nominal interest rates and a fiscal authority determining the level of government expenditures, taxes, and government debt. In particular, fiscal choices are subject to a budget constraint given by

$$B_t = R_{t-1}B_{t-1} - P_t l_t + P_t g_t$$

The financing decisions of the government, i.e., tax versus debt financing, do not matter for equilibrium determination because Ricardian equivalence applies as long as the implied paths for the debt level satisfy the no-Ponzi constraint (5) and the transversality constraint (6) for all contingencies. For sake of simplicity, we assume taxes to be set such that the real debt level $\frac{B_t}{P_t}$ lies in a closed, bounded, and positive interval for all possible events. Constraints (5) and (6) then hold by assumption and we can ignore them from now on.

3.3 Private Sector Equilibrium

In a symmetric equilibrium the relative price is given by $r_t = 1$ for all t. Given the assumptions made in the previous section, the first order conditions of households can be condensed into a price setting equation

$$u_c(c_t, h_t, g_t, \xi_t)(\Pi_t - 1)\Pi_t = \frac{u_c(c_t, h_t, g_t, \xi_t) z_t h_t}{\theta} \left(1 + \eta + \frac{u_h(c_t, h_t, g_t, \xi_t)}{u_c(c_t, h_t, g_t, \xi_t)} \frac{\eta}{z_t} \right) + \beta E_t \left[u_c(c_{t+1}, h_{t+1}, g_{t+1}, \xi_{t+1})(\Pi_{t+1} - 1)\Pi_{t+1} \right] \tag{9}$$

and a consumption Euler equation

$$\frac{u_c(c_t, h_t, g_t, \xi_t)}{R_t} = \beta E_t \left[\frac{u_c(c_{t+1}, h_{t+1}, g_{t+1}, \xi_t)}{\Pi_{t+1}} \right] \tag{10}$$

Appendix A.1 shows the explicit expressions implied by our actual choice of the utility function. Linearized versions of the price setting equation (9) appear commonly in the recent New Keynesian literature, e.g., Clarida et al. (1999).

A rational expectations equilibrium is then a set of plans $\{c_t, h_t, B_t, P_t\}$ satisfying (9) and (10) and also

$$c_t + \frac{\theta}{2}(\Pi_t - 1)^2 + g_t = z_t h_t \tag{11}$$

$$B_t = B_{t-1}R_{t-1} - l_t P_t + g_t \tag{12}$$

given policies $\{g_t, l_t, R_t \geq 1\}$, the exogenous processes $\{z_t, \xi_t\}$, and the initial conditions $R_{-1}B_{-1}$ and P_{-1}.

4 Monetary and Fiscal Policy Regimes

This section introduces the policy regimes analyzed in the remaining part of the paper. We mainly consider policymakers that maximize the utility of the representative agent. While the descriptive realism of this assumption is open to debate, importantly it allows us to isolate the inefficiencies generated by sequential policy decisions.

Monetary and fiscal policymakers are both subject to a time-inconsistency problem, being tempted to reduce the output distortion generated by monopolistic competition. Such temptations arise because sequentially acting policymakers fail to take into account that, besides affecting current variables, their decisions also affect (past) private sector expectations. Consequently, they fail to correctly assess the welfare costs of their policy decisions, namely they underestimate the welfare costs of inflation and government spending.

The timing of events is as follows. Policymakers with commitment power determine (contingent) policies at time zero, i.e., before the start of the economy. Instead, policymakers that decide sequentially determine their policy at the time of implementation, i.e., period-by-period. Each period the following standard sequence of events takes place:

Step 1: Shocks z_t and ξ_t realize.

Step 2: Monetary and fiscal policies are implemented.

Step 3: Private sector decisions are taken.

Whether monetary policy is implemented before, simultaneously, or after fiscal policy in step 2 will not matter for the equilibrium outcomes in this paper. The following subsections provide a detailed description of the various policy regimes that we analyze.

4.1 Ramsey Policy

As a benchmark we consider the Ramsey policy problem, which assumes full commitment and cooperation between monetary and fiscal policymakers:[1]

$$\max_{\{c_t,h_t,\Pi_t,R_t,g_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, g_t, \xi_t) \tag{13}$$

$$\text{s.t.:}$$

$$\text{Equations } (9), (10), (11) \text{ for all } t$$

$$R_t \geq 1 \text{ for all } t$$

Therefore, the Ramsey planner maximizes the utility function of the representative agent subject to the implementability constraints (9) and (10), the feasibility constraint (11), and the lower bound on nominal interest rates. We thus propose the following definition.

Definition 1 (Ramsey) *A Ramsey equilibrium is a state-contingent sequence for* $\{c_t, h_t, \Pi_t, R_t, g_t\}_{t=0}^{\infty}$ *that solves problem (13).*

For future reference, let

$$R^*(s^t) \text{ and } g^*(s^t)$$

denote the optimal interest rate and government spending policies, respectively, that implement the Ramsey equilibrium.

4.2 Combinations of Sequential Decisions and Commitment

We now consider separate monetary and fiscal authorities and assume that one of these policymakers decides sequentially while the other credibly commits to a policy at time zero.

4.2.1 Self-Confirming Equilibrium versus Nash Equilibrium

A policy strategy is a mapping from the history of shocks s^t and the history of past play to current actions. The strategy of the monetary authority can thus be represented by a sequence of functions $\left\{R(s^t, g^{t-1}, R^{t-1})\right\}_{t=0}^{\infty}$.[2] When recursively substituting out the history of own past play, one obtains the somewhat simpler representation $\left\{R(s^t, g^{t-1})\right\}_{t=0}^{\infty}$. Similarly, the strategy of the fiscal policymaker has a corresponding representation $\left\{g(s^t, R^{t-1})\right\}_{t=0}^{\infty}$.

[1] Since Ricardian equivalence holds we ignore the financing decisions of the fiscal authority and the initial debt level $B_{-1}R_{-1}$, which do not matter for equilibrium determination of the other variables. Since the initial condition P_{-1} simply normalizes the implied price level path, it can equally be ignored.

[2] Depending on the precise timing of events, the history may also contain the current policy decision of the other policy player. Whether this is the case is inessential for the subsequent arguments.

Even in a situation where only one policymaker can commit, the Ramsey equilibrium can be sustained as a Nash equilibrium. Consider, e.g., a sequential fiscal policymaker and a monetary authority that commits to the following trigger strategy

$$R_t = \begin{cases} R^*(s^t) & \text{if } t = 0 \text{ or } g_j = g^*(s^j) \text{ for all } j = 0, \ldots, t-1 \\ \overline{R} & \text{otherwise} \end{cases}$$

where $\overline{R}$ is sufficiently large. Here, the monetary authority threatens to implement the policy $\overline{R}$ should fiscal policy ever deviate from the Ramsey policy. If the fiscal policymaker correctly anticipates that future monetary policy behavior depends on its own past play and that deviations from the Ramsey fiscal policy lead to severe punishments, then it will choose $g^*(s^t)$ in all periods.[3]

Therefore, to make the problem interesting the modeler has to employ a mechanism that limits the leverage of the committing policymaker over the sequential authority. An effective way for achieving this is to restrict the beliefs of sequential authorities. Consider, e.g., a fiscal authority that holds rational expectations about the equilibrium future behavior of the committing monetary authority but ignores that future monetary policy actions depend directly on own past actions. Formally, such a fiscal policymaker expects the committing monetary authority to follow the policy $R(s^t)$, which is obtained by recursively substituting the strategies $\{R(s^t, g^{t-1})\}$ and $\{g(s^t, R^{t-1})\}$ into each other.[4] Along the equilibrium path one has the identity $R(s^t) = R(s^t, g^{t-1})$, while off-equilibrium the two strategies will typically differ.

Making this assumption implies that we compute a 'self-confirming equilibrium' rather than a Nash-equilibrium whenever one of the policymakers can commit and the other decides sequentially, see Fudenberg and Levine (1993) for a detailed discussion and Sargent (1999) for an application in a macroeconomic context.

Computing a self-confirming equilibrium appears to be attractive in this context for a number of reasons. First, it effectively limits the leverage of the committing authority because only actions taken in equilibrium can be used to influence the other authority. In other terms, off-equilibrium threats that are never executed cannot be employed to influence the equilibrium behavior of the sequential authority.

Second, the sequential authority's expectations are fully consistent, i.e., there is no contradiction between beliefs and outcomes: off-equilibrium events are simply never observed.

[3] Similar arguments can be made for the case where fiscal policy commits and monetary policy is decided sequentially.

[4] First, use the fiscal policy functions to elminate direct dependence of monetary policy on lagged fiscal decisions. Then use the monetary policy functions to eliminate dependence on past monetary policy decisions.

Finally, although the leverage of the committing player on the sequentially deciding player is restricted, the strategy space of the committing player remains fully unrestricted.

4.2.2 Sequential Fiscal Policy (SFP)

Given the assumptions of the previous section, the fiscal authority's maximization problem in period t is:

$$\max_{\{c_{t+j}, h_{t+j}, \Pi_{t+j}, g_{t+j}\}} E_t \sum_{j=0}^{\infty} \beta^j u(c_{t+j}, h_{t+j}, g_{t+j}, \xi_{t+j}) \tag{14}$$

$$\text{s.t.:}$$

$$\text{Equations } (9), (10), (11) \text{ for all } t$$

$$R(s^{t+j}) \text{ given for } j \geq 0$$

As shown in appendix A.2, the first order conditions of problem (14) give rise to the following result.

Lemma 2 *Optimal sequential fiscal policy sets*

$$g_t = \frac{\omega_1}{\omega_0} z_t (1 - h_t) \left(1 - \frac{\Pi_t - 1}{2\Pi_t - 1} \left[1 + \eta - \frac{\omega_0 \eta}{z_t \left(\xi_t c_t\right)^{-\sigma}} \frac{1}{(1 - h_t)^2}\right]\right) \tag{15}$$

This lemma shows that sequential fiscal policy can be expressed as a function of the current shocks s_t and the current private sector choices only. Since the latter depend on monetary policy, which in turn depends on the whole history s^t of the shocks, sequential fiscal policy choices will also be history dependent, despite sequential fiscal decision making.

The monetary policymaker rationally anticipates that the sequential fiscal policymaker follows (15). The monetary policy problem at time zero is thus given by:

$$\max_{\{c_t, h_t, \Pi_t, R_t, g_t\}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, g_t, \xi_t) \tag{16}$$

$$\text{s.t.:}$$

$$\text{Equations } (9), (10), (11), (15) \text{ for all } t$$

$$R_t \geq 1 \text{ for all } t$$

As is easily shown, the solution to problem (16) also solves the sequential policy problem (14), i.e., equation (15) is the only constraint sequential fiscal policy imposes on monetary policy. We can thus write the following definition.

Definition 3 (SFP) *An equilibrium with sequential fiscal policy and monetary commitment is a state-contingent sequence for* $\{c_t, h_t, \Pi_t, R_t, g_t\}_{t=0}^{\infty}$ *that solves problem (16).*

4.2.3 Sequential Monetary Policy (SMP)

We now consider the opposite case with sequential monetary policy and fiscal commitment. The monetary authority's maximization problem in period t is:

$$\max_{\{c_{t+j},h_{t+j},\Pi_{t+j},R_{t+j}\}} E_t \sum_{j=0}^{\infty} \beta^j u(c_{t+j}, h_{t+j}, g_{t+j}, \xi_{t+j}) \tag{17}$$

$$\begin{gathered} \text{s.t.:} \\ \text{Equations } (9), (10), (11) \text{ for all } t \\ g(s^{t+j}) \text{ given for } j \geq 0 \\ R_{t+j} \geq 1 \text{ for all } j \geq 0 \end{gathered} \tag{18}$$

Using the first order conditions the following result is derived in appendix A.3.

Lemma 4 *Optimal sequential monetary policy sets nominal interest rates so to satisfy*

$$\begin{aligned} 0 = &\frac{z_t \xi_t (1-h_t)}{\omega_0 (\xi_t c_t)^{\sigma}} \left(1 + \eta - \frac{2\Pi_t - 1}{\Pi_t - 1}\right) + \frac{2\Pi_t - 1}{\Pi_t - 1} \\ &- \frac{\eta \xi_t}{1-h_t} + \frac{\sigma}{c_t} \left[\theta(\Pi_t - 1)\Pi_t - z_t h_t (1+\eta)\right] \end{aligned} \tag{19}$$

Sequential monetary policy is set so to satisfy equation (19), which depends on current shocks and current private sector choices. Since fiscal policy and thus private sector behavior depend on the entire history s^t of shocks, monetary policy will also be history dependent, despite monetary policy being sequential.

The fiscal authority rationally anticipates that the monetary policymaker follows (19). The fiscal policy problem at time zero is thus given by:

$$\max_{\{c_t,h_t,\Pi_t,R_t,g_t\}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, g_t, \xi_t)) \tag{20}$$

$$\begin{gathered} \text{s.t.:} \\ \text{Equations } (9), (10), (11), (19) \text{ for all } t \\ R_t \geq 1 \text{ for all } t \end{gathered}$$

It is straightforward to show that a solution to problem (20) also solves the sequential monetary policy problem (17), i.e., equation (19) is the only constraint sequential monetary policy imposes on fiscal policy. We thus have the following definition.

Definition 5 (SMP) *An equilibrium with sequential monetary policy and, fiscal commitment is a state-contingent sequence for* $\{c_t, h_t, \Pi_t, R_t, g_t\}_{t=0}^{\infty}$ *that solves problem (20).*

4.3 Sequential Monetary and Fiscal Policy (SMFP)

Finally, we consider the case where both policymakers act sequentially. The maximization problem is then given by:

$$\max_{\{c_{t+j},h_{t+j},\Pi_{t+j},R_{t+j},g_{t+j}\}} E_t \sum_{j=0}^{\infty} \beta^j u(c_{t+j}, h_{t+j}, g_{t+j}, \xi_{t+j}) \tag{21}$$

$$\begin{gathered} \text{s.t.:} \\ \text{Equations } (9), (10), (11) \text{ for all } t \\ g(s^{t+j}) \text{ and } R(s^{t+j}) \text{ given for } j > 0 \\ R_{t+j} \geq 1 \text{ for all } j \geq 0 \end{gathered} \tag{22}$$

Considering a single policymaker deciding about both policy instruments instead of separate policy authorities does not affect the results since both policymakers pursue the same objective.[5] Furthermore, when taking future policy choices as given, current policy will depend on the current shocks s_t only, which justifies the initial conjecture that future choices are beyond current control. The self-confirming equilibrium thus corresponds to a Markov-perfect Nash equilibrium in this case. This brings to the following definition.

Definition 6 (SMFP) *An equilibrium with sequential monetary and fiscal policy is a state-contingent sequence for* $\{c_t, h_t, \Pi_t, R_t, g_t\}_{t=0}^{\infty}$ *that solves problem (21).*

5 Model Calibration

To understand the quantitative relevance of the different policy arrangements proposed, we calibrate the model as is summarized in table 2.

We choose the quarterly discount factor to match the average ex-post U.S. real interest rate, 3.5%, during the period 1983:1-2002:4. The choice for the elasticity of demand implies a gross mark-up equal to 1.2. Consumption utility is assumed logarithmic. The values of ω_0 and ω_1 are chosen such that in the Ramsey steady state agents work 20% of their time and spend 20% of output on public goods.[6] The price stickiness parameter is chosen such that the log-linearized version of the Phillips curve (9) is consistent with the estimates of Sbordone (2002), as in Schmitt-Grohé and Uribe (2004). Technology and preference shocks are assumed to be sufficiently persistent.[7]

[5] Appendix A.2 shows how (15) can be derived from the first order conditions of (21). Likewise appendix A.3 shows how (19) can be derived from the first order conditions of (21). Therefore, imposing (15) or (19) turns out to be irrelevant.

[6] The values of ω_0 and ω_1 are set according to equations (32) and (35) in appendix A.4.2.

[7] The persistence parameters ρ_z and ρ_ξ influence the impulse responses only. The variances of the shock innovations can be left unspecified because we compute a linear approximation to the equilibrium dynamics.

To test the robustness of our results, we consider also alternative model parametrizations. And to increase comparability across parametrizations., the values of the utility parameters ω_0 and ω_1 will be adjusted in a way that the Ramsey steady state remains unaffected by the considered parameter change.

Variable	**Assigned Value**
discount factor	$\beta = 0.9913$
elasticity of demand	$\eta = -6$
adjustment cost parameter	$\theta = 17.5$
elasticity of substitution	$\sigma = 1$
utility weight on leisure	$\omega_0 = 4.1\overline{6}$
utility weight on the public good	$\omega_1 = 0.2152\overline{3}$
persistence of technology shocks	$\rho_z = 0.8$
persistence of preference shocks	$\rho_\xi = 0.8$

Table 1: Baseline parameterization

6 Solution Strategy

This section outlines the strategy we employ for solving policy problems (13), (16), (20), and (21). A more detailed account is provided in appendix A.4.

We first derive recursive formulations of the policy problems. The recursive formulations have nonlinear recursive objectives and linear transition laws. Using the first order conditions of the recursive problems we numerically compute the deterministic steady states. Due to the monopolistic distortion and sequential policy decisions, these steady states fail to be first best.

We then take a quadratic approximation to the recursive objective around the steady state. In the case of the Ramsey problem (13), e.g., this involves quadratically approximating the utility functions as well as the implementability constraints. This generates linear-quadratic control problems that one can solve using standard methods. The solutions of the linear quadratic problems deliver a first order approximation to the equilibrium dynamics and a second order approximation to the welfare of the representative agent, as in Benigno and Woodford (2003).

Solving the SMFP problem (21) requires an additional step. Since expected future values are taken as given, a complete description of the policy problem requires specifying forecasting functions. The solution to the problem, i.e., the derived policy functions, has to be consistent with these forecasting functions. Therefore, one has to iterate on the forecasting functions until consistency is achieved.

Conceptually, our solution approach is equivalent to solving the linearized first order conditions of the problems (13), (16), (20), and (21). Importantly, however, our approach allows to check whether second order conditions do hold for the solutions we derive. This is important since some of the implementability constraints fail to be concave.[8] As shown in Adam and Billi (2004), for a nonlinear problem, we check second order conditions by numerically verifying the saddlepoint property of the recursive policy problems.

7 Steady State Effects

Due to the time-inconsistency of optimal policy, sequential policy decisions are sub-optimal. This section illustrates how the steady state values of the endogenous variables and the steady state utility levels are affected by the various policy arrangements under scrutiny. Table 2 summarizes the steady effects on private consumption, fiscal spending, working hours, inflation, and welfare. Results are presented in terms of percentage deviations from the Ramsey outcome.[9]

First, consider the SFP regime in table 2. Sequential fiscal decisions generate an increase in fiscal spending. Moreover, they crowd-out private consumption, lead to an increase in hours worked, and generate some inflation. While the latter effects reduce the utility of the private agent, higher fiscal spending is welfare increasing. Overall, the utility costs of sequential fiscal spending decisions are negligible, and the size of the fiscal spending bias is rather moderate.

Policy regime	private consumption	fiscal spending	working hours	inflation (annual rate)	steady state utility
SFP	-0.13%	+3.18%	+0.53%	+0.04%	-0.0032%
SMP	-0.20%	+1.95%	+1.99%	+8.02%	-0.5386%
SMFP	-0.13%	+0.31%	+1.73%	+8.04%	-0.5394%

Table 2: Steady state effects (relative to the Ramsey solution)

Second, consider the opposite case with sequential monetary policy and fiscal commitment (SMP). This arrangement generates the familiar inflation bias associated with sequential monetary policy decisions in sticky price economies, see the corresponding row in table 2. Since inflation generates resource costs, the private sector reacts to it by reducing consumption and leisure (i.e., increasing working hours). Quite surprisingly, despite fiscal commitment SMP also generates a fiscal spending bias.

[8] The implementability constraint (19) arising from sequential monetary policy, e.g., is not concave in Π_t.

[9] In the Ramsey steady state $c = 0.16$, $g = 0.04$, $h = 0.2$, and $\Pi = 1$.

The optimality of increased fiscal spending can be understood as follows. Monetary policy aims to higher inflation in an attempt to increase output. Inflation is increased up to the point where the marginal costs of inflation equals the marginal utility of additional output. Ultimately, however, monetary policy fails to increase output and generates inflation only. In such a situation fiscal spending is optimal precisely because it generates inflation (via an increase in hours and an increase in inflation expectations). Part of the unavoidable inflation generated by monetary policy can thus be 'transformed' into fiscal spending, which increases welfare.

Note that the welfare losses generated by sequential monetary policy are considerable, namely two orders of magnitude larger than for sequential fiscal policy (SFP). This can be explained as follows. Monetary policy increases the inflation rate to the point where the marginal costs of inflation balance the marginal utility of an additional unit of output generated by 'surprise' inflation. The marginal utility of output either stays constant, due to long-run neutrality, or even increases because of the resource costs associated with positive rates of inflation. Monetary policy thus operates either on a single margin or on two margins of which one moves in the 'wrong', i.e., non-equilibrating, direction. Fiscal policy, however, is effective in increasing (public) consumption and therefore operates on two equilibrating margins: it balances the marginal utility of (public) consumption, which is falling in the level of public consumption, to the marginal costs of reducing private consumption, creating inflation, and reducing leisure, all of which are increasing in the level of public spending.

The previous arguments also reveal why a committed fiscal policymaker is not more successful in 'transforming' the inflation bias into a (less costly) government spending bias. Public spending crowds-out private consumption and thereby increases the marginal utility of output. This increases the incentive for the monetary authority to generate surprise inflation.

Finally, consider the case with sequential monetary and fiscal policy (SMFP) in table 2 . The result resembles closely that of sequential monetary policy and fiscal commitment (SMP). The most notable difference is the seemingly paradoxical result that public spending drops once one allows also for sequential fiscal policy. This occurs because a sequential fiscal authority takes inflation expectations as given, thus, does not fully take into account the effects of fiscal spending on inflation. As a result, public spending is considered to be a less powerful tool for 'transforming' the monetary inflation bias into a (less costly) public spending bias.

Overall, the welfare gains from commitment to fiscal spending plans appear negligible. Welfare decreases only slightly when comparing SFP regime to the Ramsey allocation or the SMFP regime to the outcome with SMP. Sequential monetary policy, however, generates sizable welfare losses, independently of whether fiscal policy can commit. Table 3 illustrates the robustness of these findings to different parametrizations of the model.

Steady state utility relative to Ramsey	**SFP**	**SMP**	**SMFP**
baseline calibration	-0.0032%	-0.5386%	-0.5394%
less flexible prices ($\theta = 25$)	-0.0032%	-0.6551%	-0.6559%
more flexible prices ($\theta = 10$)	-0.0032%	-0.3770%	-0.3776%
more competition ($\eta = -7$)	-0.0022%	-0.3162%	-0.3166%
less competition ($\eta = -5$)	-0.0049%	-0.9526%	-0.9540%
lower discount factor ($\beta = 0.98$)	-0.0032%	-0.5015%	-0.5022%
higher discount factor ($\beta = 0.995$)	-0.0032%	-0.5512%	-0.5521%
higher risk aversion ($\sigma = 2$)	-0.0013%	-0.2701%	-0.2703%
lower risk aversion ($\sigma = 1/2$)	-0.0070%	-0.9829%	-0.9860%

Table 3: Robustness of steady state utility effects

8 Impulse Responses

Beyond affecting the steady state values of endogenous variables, different monetary and fiscal policy regime also influence the response of the economy to technology and preference shocks. Suboptimal policy responses to shocks may be an additional source of welfare losses generated by sequential decision making.

Figure 1 illustrates the impulse responses corresponding to the baseline calibration of section 5.[10] The left-hand side panels depict the responses to a positive technology shock. Private and public consumption increase and nominal interest rates fall in all policy regimes. The reaction of hours worked and inflation depends on whether or not monetary policy can commit, however, differences across regimes are quantitatively small. They arise because a positive technology shocks reinforces the inflation bias generated by sequential monetary policy. Inflation is thus temporarily higher with SMP and SMFP. The left-hand

[10] All variables are expressed as percentage deviations from steady state values. Interest rates and inflation rates are annualized.

side panels of figures 2 and 3 display the impulse responses when the coefficient of relative risk aversion is higher ($\sigma = 2$) or lower ($\sigma = 1/2$), respectively, than the baseline ($\sigma = 1$). The reaction of hours worked to a technology shock is virtually the same across all policy regimes, while differences in the responses of inflation remain quantitatively small. Therefore, impulse responses to a technology shock are surprisingly stable across the considered policy regimes.

The right-hand side panels of figure 1 display the impulse response to a preference shock that temporarily reduces the marginal utility of consumption. The shape of the impulse responses mainly depends on whether or not monetary policy can commit. With monetary commitment impulse responses closely resemble the Ramsey outcome independently of whether or not fiscal policy is determined sequentially. With sequential monetary policy, however, interest rates fail to react to the preference shock. This leads to a larger drop in both private consumption and hours worked and longer lasting inflation than in the Ramsey case. Impulse responses for different values of the coefficient of relative risk aversion are depicted in the right-hand side panels of figures 2 and 3. Lower relative risk aversion amplifies the difference in the impulse responses for consumption and hours worked across regimes with and without monetary commitment, while higher values of relative risk aversion cause impulse responses to be more similar. Overall, the impulse responses seem relatively stable across policy regimes with differences mainly depending on whether or not monetary policy can commit.

9 Conservative Central Bank

This section analyzes whether well-known policy proposals such as Rogoff's (1985) 'weight conservative' central bank or Svensson's (1997) 'target conservative' central bank are successful in ameliorating the inflation bias generated by sequential monetary policy in a setting with endogenous fiscal policy. The usefulness of making the central bank conservative in a setting with endogenous fiscal policy has recently been questioned by Dixit and Lambertini (2003a).

We consider a sequential monetary policymaker maximizing

$$E_t \sum_{j=0}^{\infty} \beta^j \left(u(c_{t+j}, h_{t+j}, g_{t+j}, \xi_{t+j}) - \frac{\alpha}{2}(\Pi_t - T)^2 \right) \tag{23}$$

where T denotes an inflation target and α the weight given to squared deviations from it. For $\alpha > 0$ and $T = 1$ one obtains a weight conservative central bank along the lines of Rogoff (1985). Instead, for $\alpha > 0$ and $T < 1$ one gets a target conservative central bank, as studied in Svensson (1997).

Substituting the objective function of the sequential policy problem (17) with the conservative objective (23), one can then use the first order conditions to obtain the following result.

Lemma 7 *With a conservative central bank optimal sequential monetary policy sets nominal interest rates so to satisfy*

$$0 = \frac{\alpha\frac{1}{\theta}\frac{\Pi_t - T}{2\Pi_t - 1} - \frac{c_t}{\sigma}\frac{\xi_t}{(c_t\xi_t)^\sigma(-h_t z_t(\eta+1)+\theta\Pi_t(\Pi_t-1))}}{-\frac{\Pi_t-1}{2\Pi_t-1} - \frac{c_t}{\sigma}\frac{1}{-h_t z_t(\eta+1)+\theta\Pi_t(\Pi_t-1)}}$$
$$+ \frac{\frac{\omega_0}{z_t(1-h_t)}\left(-h_t z_t(\eta+1)+\theta\Pi_t(\Pi_t-1)\right) + \frac{c_t}{\sigma}\frac{\xi_t}{(c_t\xi_t)^\sigma}\left(\eta - \frac{\eta\omega_0}{z_t}\frac{(c_t\xi_t)^\sigma}{(1-h_t)^2}+1\right)}{h_t z_t(\eta+1) - \theta\Pi_t(\Pi_t-1) - \frac{c_t}{\sigma}\left(\eta - \frac{\eta\omega_0}{z_t}\frac{(c_t\xi_t)^\sigma}{(1-h_t)^2}+1\right)} \tag{24}$$

The constraint (24) is consistent with the Ramsey steady state, in which $\Pi_t = \xi_t = z_t = 1$, whenever

$$\alpha(T-1) = -\frac{c}{h}\frac{\theta}{\sigma(\eta+1)}\left(\frac{1}{c^\sigma} - \frac{\frac{h}{1-h}\omega_0(\eta+1) - \frac{c^{1-\sigma}}{\sigma}\left(\eta - c^\sigma\frac{\eta\omega_0}{(1-h)^2}+1\right)}{h(\eta+1) - \frac{c}{\sigma}\left(\eta - c^\sigma\frac{\eta\omega_0}{(1-h)^2}+1\right)}\right) \tag{25}$$

where variables without time subscript denote their Ramsey steady state values. Equation (25) shows that for $T = 1$ a finite value of α will not achieve consistency with the Ramsey steady state, i.e., a target conservative central bank is required to completely eliminate steady state distortions.

If fiscal policy can commit and monetary policy is appropriately conservative, in the sense that equation (25) is satisfied, then the steady state resulting from monetary and fiscal interactions is second best. Monetary conservatism, thus, eliminates the steady state distortions associated with sequential monetary policy making.

If monetary and fiscal policy are both determined sequentially, then we find that monetary conservatism that satisfies equation (25) eliminates steady state welfare losses associated with sequential monetary and fiscal policy almost completely. For the baseline calibration from table 1, steady state losses are three orders of magnitude lower than those generated in the SMFP regime and thus also one order of magnitude lower than in the SFP regime. Monetary conservatism thus not only eliminates the losses generated by sequential monetary policy but also almost fully eliminates those generated by sequential fiscal policy.

10 Conclusions

This paper analyzes monetary and fiscal policy interactions in a stochastic dynamic general equilibrium model when some or all policymakers lack the ability to credibly commit to policies ex-ante.

It is shown that, independently of whether or not monetary policy can commit, sequential fiscal decisions about the level of public goods provision generate only limited steady state welfare losses. Instead, sequential monetary policy generates an inflation bias, a fiscal spending bias and a sizable steady state welfare loss. Analyzing impulse responses to technology and preference shocks, the optimal evolution of the economy is found to depend mainly on whether or not monetary policy can commit. Monetary commitment, thus, appears to be the main factor determining the welfare level achieved by a particular policy regime.

In the absence of monetary commitment but as long as fiscal policy can commit, making the monetary authority appropriately conservative completely eliminates the steady state distortions associated with sequential monetary policy. The case for a conservative monetary authority is even stronger since monetary conservatism would also almost fully eliminate the steady state losses associated with sequential fiscal policy.

A number of important questions remain open and ought to be addressed in further research. First, this paper assumes the existence of lump sum taxes. Financing excessive fiscal provision of public goods, therefore, does not generate any deadweight losses. This feature may partly explain the fact that sequential fiscal policy does not generate significantly large welfare losses. Analyzing the robustness of this result to the presence of a distortionary tax system is of interest.

Second, the paper abstracts from capital and capital stock dynamics. The existence of endogenous state variables allows for a richer structure of interactions between policymakers and it seems interesting to explore the consequences of such interactions in detail. We expect the self-confirming equilibrium introduced in this paper to prove a useful tool for computing equilibria in such richer settings.

A Appendix

A.1 Euler Equation and Phillips Curve

Given the utility specification equations (9) and (10), respectively, can be expressed as

$$\begin{aligned}(\Pi_t - 1)\Pi_t \theta \left(\xi_t c_t\right)^{-\sigma} &= z_t h_t \left(\xi_t c_t\right)^{-\sigma} \left(1 + \eta - \frac{\omega_0}{(1-h_t)\left(\xi_t c_t\right)^{-\sigma}} \frac{\eta}{z_t}\right) \\ &\quad + \beta E_t \left[\left(\xi_{t+1} c_{t+1}\right)^{-\sigma} (\Pi_{t+1} - 1)\Pi_{t+1}\right] \qquad (26)\\ \frac{\left(\xi_t c_t\right)^{-\sigma}}{R_t} &= \beta E_t \left[\frac{\left(\xi_{t+1} c_{t+1}\right)^{-\sigma}}{\Pi_{t+1}}\right] \qquad (27)\end{aligned}$$

A.2 Sequential Fiscal Policy

Let Λ^{SF} denote the Lagrangian associated with the sequential fiscal spending problem (14) and let γ_t^{SF1}, γ_t^{SF2}, γ_t^{SF3} denote the Lagrange multipliers associated with constraints (9), (10), and(11), respectively. The first order conditions (FOCs) with respect to (c_t, h_t, Π_t, g_t) are given by:

$$\begin{aligned}
\frac{\partial\Lambda^{SF}}{\partial c_t}: \quad 0 = \; & \xi_t\left(\xi_t c_t\right)^{-\sigma} + \gamma_t^{SF1}\tfrac{h_t\omega_0\eta\sigma}{(1-h_t)c_t} \\
& -\gamma_t^{SF1}\left[\theta(\Pi_t-1)\Pi_t - z_t h_t\left(1+\eta-\tfrac{\omega_0\eta}{z_t(1-h_t)(\xi_t c_t)^{-\sigma}}\right)\right]\sigma\xi_t\left(\xi_t c_t\right)^{-\sigma-1} \\
& -\tfrac{\gamma_t^{SF2}}{R_t}\sigma\xi_t\left(\xi_t c_t\right)^{-\sigma-1} - \gamma_t^{SF3} \\
\frac{\partial\Lambda^{SF}}{\partial h_t}: \quad 0 = \; & -\tfrac{\omega_0}{1-h_t} + \gamma_t^{SF3} z_t \\
& -\gamma_t^{SF1}\left(\xi_t c_t\right)^{-\sigma} z_t\left[1+\eta-\tfrac{\omega_0\eta}{z_t(1-h_t)(\xi_t c_t)^{-\sigma}} - \tfrac{h_t\omega_0\eta}{z_t(1-h_t)^2(\xi_t c_t)^{-\sigma}}\right] \\
\frac{\partial\Lambda^{SF}}{\partial\Pi_t}: \quad 0 = \; & \gamma_t^{SF1}\left(\xi_t c_t\right)^{-\sigma}\theta\left(2\Pi_t-1\right) - \gamma_t^{SF3}\theta(\Pi_t-1) \\
\frac{\partial\Lambda^{SF}}{\partial g_t}: \quad 0 = \; & \tfrac{\omega_1}{g_t} - \gamma_t^{SF3}
\end{aligned}$$

From the FOC w.r.t. Π_t we have

$$\gamma_t^{SF1} = \gamma_t^{SF3}\frac{\Pi_t-1}{\left(\xi_t c_t\right)^{-\sigma}\left(2\Pi_t-1\right)}$$

Substituting this into the FOC w.r.t. h_t one obtains

$$\gamma_t^{SF3} = \frac{\omega_0}{z_t\left(1-h_t\right)\left(1-\frac{\Pi_t-1}{2\Pi_t-1}\left[1+\eta-\frac{\omega_0\eta}{z_t(1-h_t)^2(\xi_t c_t)^{-\sigma}}\right]\right)}$$

Combining this with the FOC w.r.t. g_t delivers

$$g_t = \frac{\omega_1}{\omega_0}z_t(1-h_t)\left(1-\frac{\Pi_t-1}{2\Pi_t-1}\left[1+\eta-\frac{\omega_0\eta}{z_t\left(\xi_t c_t\right)^{-\sigma}}\frac{1}{(1-h_t)^2}\right]\right) \qquad (28)$$

A.3 Sequential Monetary Policy

Let Λ^{SM} denote the Lagrangian associated with the sequential monetary policy problem (17) and let γ_t^{SM1}, γ_t^{SM2}, γ_t^{SM3}, and γ_t^{SM3} denote the Lagrange multipliers associated with constraints (9), (10), (11), and (15), respectively. The first order conditions (FOCs) with respect to (c_t, h_t, Π_y, R_t) are given by:

$$\begin{aligned}
\frac{\partial\Lambda^{SM}}{\partial c_t}: \quad 0 = \; & \xi_t\left(\xi_t c_t\right)^{-\sigma} \\
& -\gamma_t^{SM1}\left[\theta(\Pi_t-1)\Pi_t - z_t h_t\left(1+\eta\right)\right]\sigma\xi_t\left(\xi_t c_t\right)^{-\sigma-1} \\
& -\tfrac{\gamma_t^{SM2}}{R_t}\sigma\xi_t\left(\xi_t c_t\right)^{-\sigma-1} - \gamma_t^{SM3} \\
\frac{\partial\Lambda^{SM}}{\partial h_t}: \quad 0 = \; & -\tfrac{\omega_0}{1-h_t} + \gamma_t^{SM3} z_t \\
& -\gamma_t^{SM1}\left(\xi_t c_t\right)^{-\sigma} z_t\left[1+\eta-\tfrac{\omega_0\eta}{z_t(1-h_t)^2(\xi_t c_t)^{-\sigma}}\right] \\
\frac{\partial\Lambda^{SM}}{\partial\Pi_t}: \quad 0 = \; & \gamma_t^{SM1}\left(\xi_t c_t\right)^{-\sigma}\theta\left(2\Pi_t-1\right) - \gamma_t^{SM3}\theta(\Pi_t-1) \\
\frac{\partial\Lambda^{SM}}{\partial R_t}(R_t-1): \quad 0 = \; & -\gamma_t^{SM2}\tfrac{(\xi_t c_t)^{-\sigma}}{R_t^2}(R_t-1)
\end{aligned}$$

The FOC w.r.t. R_t implies

$$\gamma_t^{SM2} = 0$$

as long as $R_t > 1$. Using this one can eliminate the Lagrange multipliers from the FOCs w.r.t. (c_t, h_t, Π_t). This delivers

$$\begin{aligned} 0 = & \frac{z_t \xi_t (1 - h_t)}{\omega_0 (\xi_t c_t)^{\sigma}} \left(1 + \eta - \frac{2\Pi_t - 1}{\Pi_t - 1}\right) + \frac{2\Pi_t - 1}{\Pi_t - 1} \\ & - \frac{\eta \xi_t}{1 - h_t} + \frac{\sigma}{c_t} \left[\theta(\Pi_t - 1)\Pi_t - z_t h_t (1 + \eta)\right] \end{aligned} \tag{29}$$

A.4 Strategy for Solving the Policy Problems

We describe here the recursive formulations used for the solving the policy problems, that are derived along the lines proposed by Marcet and Marimon (1998).

A.4.1 Ramsey Problem

The recursive formulation of problem (13) is

$$W\left(z_t, \mu_t^1, \xi_t, \mu_t^2\right) = \inf_{(\gamma_t^1, \gamma_t^2, \gamma_t^3)} \sup_{(c_t, h_t, \Pi_t, R_t, g_t)} \left\{ f(\cdot) + \beta E\left[W\left(z_{t+1}, \mu_{t+1}^1, \xi_{t+1}, \mu_{t+1}^2\right)\right]\right\} \tag{30}$$

$$\begin{aligned} & \text{s.t.:} \\ & R_t \geq 1 \\ & z_t = (1 - \rho_z) + \rho_Z z_{t-1} + \varepsilon_t^z, \quad && \varepsilon_t^z \sim N(0, \sigma_z^2) \\ & \mu_{t+1}^1 = \gamma_t^1, && \mu_0^1 = 0 \\ & \xi_t = (1 - \rho_\xi) + \rho_\xi \xi_{t-1} + \varepsilon_t^\xi, && \varepsilon_t^\xi \sim N(0, \sigma_\xi^2) \\ & \mu_{t+1}^2 = \gamma_t^2, && \mu_0^2 = 0 \end{aligned}$$

where

$$\begin{aligned} f(\cdot) = & \tfrac{1}{1-\sigma}\left((\xi_t c_t)^{1-\sigma} - 1\right) + \omega_0 \log(1 - h_t) + \omega_1 \log(g_t) \\ & + \gamma_t^1 (\xi_t c_t)^{-\sigma} \left[\theta(\Pi_t - 1)\Pi_t - z_t h_t \left(1 + \eta - \tfrac{\omega_0 \eta}{z_t (1-h_t)(\xi_t c_t)^{-\sigma}}\right)\right] \\ & - \mu_t^1 (\xi_t c_t)^{-\sigma} \theta(\Pi_t - 1)\Pi_t + \gamma_t^2 \tfrac{(\xi_t c_t)^{-\sigma}}{R_t} - \mu_t^2 \tfrac{(\xi_t c_t)^{-\sigma}}{\Pi_t} \\ & + \gamma_t^3 \left[z_t h_t - c_t - g_t - \tfrac{\theta}{2}(\Pi_t - 1)^2\right] \end{aligned}$$

and where γ_t^1, γ_t^2, γ_t^3 are the Lagrange multipliers associated with constraints (9), (10), and (11), respectively. We solve for the steady state using the first order conditions of this problem. We then compute a quadratic approximation to $f(\cdot)$ around this steady state and solve (30) by replacing $f(\cdot)$ with its quadratic approximation.

A.4.2 Utility Parameters and Ramsey Steady State:

Here we show how the utility parameters ω_0 and ω_1 are related to the Ramsey steady state. Let variables without subscripts denote their steady state values and consider a steady state where $\xi = z = 1$ and $\Pi = 1$. The first order condition (FOC) of (30) w.r.t. γ_t^2 implies $R = \frac{1}{\beta} > 1$. This and the FOC w.r.t. R_t delivers

$$\gamma^2 = \mu^2 = 0 \tag{31}$$

Using the FOC w.r.t. γ_t^1 one obtains

$$\omega_0 = \frac{1+\eta}{\eta}\left(1-h\right)c^{-\sigma} \tag{32}$$

The FOC w.r.t. c_t, (31), and (32) deliver

$$c^{-\sigma} + \gamma^1 \frac{h\omega_0\eta\sigma}{\left(1-h\right)c} - \gamma^3 = 0 \tag{33}$$

then the FOC w.r.t. h_t and (32) imply

$$-\frac{\omega_0}{1-h} + \gamma^1 \frac{h\omega_0\eta}{\left(1-h\right)^2} + \gamma^3 = 0 \tag{34}$$

From (33) and (34) one obtains

$$\gamma^3 = \frac{c^{1-\sigma} + \sigma\omega_0}{c + \sigma(1-h)}$$

Finally, this and the FOC w.r.t. g_t implies

$$\begin{aligned}\omega_1 &= g\gamma^3 \\ &= g\frac{c^{1-\sigma} + \sigma\omega_0}{c + \sigma(1-h)}\end{aligned} \tag{35}$$

A.4.3 Sequential Fiscal Policy (SFP)

The recursive formulation of (16) is

$$W\left(z_t, \mu_t^1, \xi_t, \mu_t^2\right) = \inf_{(\gamma_t^1,\gamma_t^2,\gamma_t^3,\gamma_t^4)} \sup_{(c_t,h_t,\Pi_t,R_t,g_t)} \left\{f\left(\cdot\right) + \beta E_t\left[W\left(z_{t+1}, \mu_{t+1}^1, \xi_{t+1}, \mu_{t+1}^2\right)\right]\right\} \tag{36}$$

$$\begin{aligned}&\text{s.t.:}\\ &R_t \geq 1\\ &z_{t+1} = (1-\rho_z) + \rho_z z_t + \varepsilon_{t+1}^z, \quad \varepsilon_t^z \sim N(0,\sigma_z^2)\\ &\mu_{t+1}^1 = \gamma_t^1, \quad \mu_0^1 = 0\\ &\xi_{t+1} = (1-\rho_\xi) + \rho_\xi \xi_t + \varepsilon_{t+1}^\xi, \quad \varepsilon_t^\xi \sim N(0,\sigma_\xi^2)\\ &\mu_{t+1}^2 = \gamma_t^2, \quad \mu_0^2 = 0\end{aligned}$$

where

$$
\begin{aligned}
f(\cdot) \quad = \quad & \tfrac{1}{1-\sigma}\left(\left(\xi_t c_t\right)^{1-\sigma}-1\right)+\omega_0 \log(1-h_t)+\omega_1 \log(g_t) \\
& +\gamma_t^1\left(\xi_t c_t\right)^{-\sigma}\left[\theta(\Pi_t-1)\Pi_t - z_t h_t\left(1+\eta-\tfrac{\omega_0 \eta}{z_t(1-h_t)(\xi_t c_t)^{-\sigma}}\right)\right] \\
& -\mu_t^1\left(\xi_t c_t\right)^{-\sigma}\theta(\Pi_t-1)\Pi_t+\gamma_t^2\tfrac{(\xi_t c_t)^{-\sigma}}{R_t}-\mu_t^2\tfrac{(\xi_t c_t)^{-\sigma}}{\Pi_t} \\
& +\gamma_t^3\left[z_t h_t-c_t-g_t-\tfrac{\theta}{2}(\Pi_t-1)^2\right] \\
& +\gamma_t^4\left[g_t-\tfrac{\omega_1}{\omega_0}z_t(1-h_t)\left(1-\tfrac{\Pi_t-1}{2\Pi_t-1}\left[1+\eta-\tfrac{\omega_0\eta}{z_t(\xi_t c_t)^{-\sigma}}\tfrac{1}{(1-h_t)^2}\right]\right)\right]
\end{aligned}
$$

and γ_t^1, γ_t^2, γ_t^3, γ_t^4 are the Lagrange multipliers associated with constraints (9), (10), (11), and (15), respectively. We then solve for the steady state using the first order conditions of this problem. Thereafter, we compute a quadratic approximation to $f(\cdot)$ around this steady state and solve (36) by replacing $f(\cdot)$ with its quadratic approximation.

A.4.4 Sequential Monetary Policy (SMP)

The recursive formulation of (20) is

$$
W\left(z_t,\mu_t^1,\xi_t,\mu_t^2\right)=\inf_{(\gamma_t^1,\gamma_t^2,\gamma_t^3,\gamma_t^4)}\ \sup_{(c_t,h_t,\Pi_t,R_t,g_t)}\left\{f(\cdot)+\beta E_t\left[W\left(z_{t+1},\mu_{t+1}^1,\xi_{t+1},\mu_{t+1}^2\right)\right]\right\} \tag{37}
$$

$$
\begin{aligned}
& \text{s.t.:} \\
& R_t \geq 1 \\
& z_{t+1}=(1-\rho_z)+\rho_z z_t+\varepsilon_{t+1}^z, \quad && \varepsilon_t^z \sim N(0,\sigma_z^2) \\
& \mu_{t+1}^1=\gamma_t^1, && \mu_0^1=0 \\
& \xi_{t+1}=(1-\rho_\xi)+\rho_\xi \xi_t+\varepsilon_{t+1}^\xi, && \varepsilon_t^\xi \sim N(0,\sigma_\xi^2) \\
& \mu_{t+1}^2=\gamma_t^2, && \mu_0^2=0
\end{aligned}
$$

where

$$
\begin{aligned}
f(\cdot) \quad = \quad & \tfrac{1}{1-\sigma}\left(\left(\xi_t c_t\right)^{1-\sigma}-1\right)+\omega_0 \log(1-h_t)+\omega_1 \log(g_t) \\
& +\gamma_t^1\left(\xi_t c_t\right)^{-\sigma}\left[\theta(\Pi_t-1)\Pi_t - z_t h_t\left(1+\eta-\tfrac{\omega_0 \eta}{z_t(1-h_t)(\xi_t c_t)^{-\sigma}}\right)\right] \\
& -\mu_t^1\left(\xi_t c_t\right)^{-\sigma}\theta(\Pi_t-1)\Pi_t+\gamma_t^2\tfrac{(\xi_t c_t)^{-\sigma}}{R_t}-\mu_t^2\tfrac{(\xi_t c_t)^{-\sigma}}{\Pi_t} \\
& +\gamma_t^3\left[z_t h_t-c_t-g_t-\tfrac{\theta}{2}(\Pi_t-1)^2\right] \\
& +\gamma_t^4\left[\begin{array}{c}\tfrac{z_t\xi_t(1-h_t)}{\omega_0(\xi_t c_t)^{\sigma}}\left(1+\eta-\tfrac{2\Pi_t-1}{\Pi_t-1}\right)+\tfrac{2\Pi_t-1}{\Pi_t-1} \\ -\tfrac{\eta\xi_t}{1-h_t}+\tfrac{\sigma}{c_t}\left[\theta(\Pi_t-1)\Pi_t-z_t h_t\left(1+\eta\right)\right]\end{array}\right]
\end{aligned}
$$

where γ_t^1, γ_t^2, γ_t^3, γ_t^4 are the Lagrange multipliers associated with constraints (9), (10), (11), and (19), respectively. We then solve for the steady state using the first order conditions of this problem. Thereafter, we compute a quadratic approximation to $f(\cdot)$ around this steady state and solve (37) by replacing $f(\cdot)$ with its quadratic approximation.

A.4.5 Sequential Monetary and Fiscal Policy (SMFP)

The recursive formulation of (21) is

$$W(z_t, \xi_t) = \inf_{(\gamma_t^1, \gamma_t^2, \gamma_t^3)} \sup_{(c_t, h_t, \Pi_t, R_t, g_t)} \{f(\cdot) + \beta E_t [W(z_{t+1}, \xi_{t+1})]\} \tag{38}$$

$$\begin{aligned}
&\text{s.t.:} \\
&R_t \geq 1 \\
&z_{t+1} = (1-\rho_z) + \rho_z z_t + \varepsilon_{t+1}^z, \quad \varepsilon_t^z \sim N(0, \sigma_z^2) \\
&\xi_{t+1} = (1-\rho_\xi) + \rho_\xi \xi_t + \varepsilon_{t+1}^\xi, \quad \varepsilon_t^\xi \sim N(0, \sigma_\xi^2)
\end{aligned}$$

where

$$\begin{aligned}
f(\cdot) = &\frac{1}{1-\sigma}\left((\xi_t c_t)^{1-\sigma} - 1\right) + \omega_0 \log(1-h_t) + \omega_1 \log(g_t) \\
&+ \gamma_t^1 \left[(\xi_t c_t)^{-\sigma} \theta(\Pi_t - 1)\Pi_t - z_t h_t (\xi_t c_t)^{-\sigma}\left(1 + \eta - \frac{\omega_0 \eta}{z_t (1-h_t)(\xi_t c_t)^{-\sigma}}\right) - E_t^{AS}\right] \\
&+ \gamma_t^2 \left[\frac{(\xi_t c_t)^{-\sigma}}{R_t} - E_t^{IS}\right] \\
&+ \gamma_t^3 \left[z_t h_t - c_t - g_t - \frac{\theta}{2}(\Pi_t - 1)^2\right]
\end{aligned}$$

$$E_t^{AS} \equiv \beta E_t \left[(\xi_{t+1} c_{t+1})^{-\sigma} \theta(\Pi_{t+1} - 1)\Pi_{t+1}\right] \tag{39}$$

$$E_t^{IS} \equiv \beta E_t \left[\frac{(\xi_{t+1} c_{t+1})^{-\sigma}}{\Pi_{t+1}}\right] \tag{40}$$

and the values of the expectations functions E_t^{AS} and E_t^{IS} are taken as given. The controls γ_t^1, γ_t^2, γ_t^3 are the Lagrange multipliers associated with constraints (9), (10), and (11), respectively. We then solve for the steady state using the first order conditions of (38). Thereafter, we compute a quadratic approximation to $f(\cdot)$ around this steady state, except for the terms E_t^{AS} and E_t^{IS} that we approximate linearly as

$$E_t^{AS} \approx \alpha_0^1 + \alpha_1^1 (z_t - 1) + \alpha_2^1 (\xi_t - 1) \tag{41}$$

$$E_t^{IS} \approx \alpha_0^2 + \alpha_1^2 (z_t - 1) + \alpha_2^2 (\xi_t - 1) \tag{42}$$

Given these expectations functions we then solve (38) by replacing $f(\cdot)$ with its approximation. This is a standard linear quadratic control problem.

Importantly, postulating linear expectations functions is sufficient to obtain a first order approximation to the equilibrium dynamics and policy functions. This is the case since the policymaker takes expectations functions as given, therefore, they do not show up in differentiated form in the first order conditions.

We now explain how we update the expectations functions. For a given initial guess of the expectations functions (41) and (42), let the solution to (38), with $f(\cdot)$ replaced by its approximation, be given by

$$c_{t+1} - c = \delta_{cz}(z_{t+1} - 1) + \delta_{c\xi}(\xi_{t+1} - 1) \tag{43}$$

$$\Pi_{t+1} - \Pi = \delta_{\Pi z}(z_{t+1} - 1) + \delta_{\Pi\xi}(\xi_{t+1} - 1) \tag{44}$$

A first order approximation of (39) and (40) delivers

$$E_t^{AS} \approx E_t^{AS}\big|_{ss} + \left.\frac{\partial E_t^{AS}}{\partial \xi_{t+1}}\right|_{ss} E_t(\xi_{t+1} - 1) + \left.\frac{\partial E_t^{AS}}{\partial c_{t+1}}\right|_{ss} E_t(c_{t+1} - c) + \left.\frac{\partial E_t^{AS}}{\partial \Pi_{t+1}}\right|_{ss} E_t(\Pi_{t+1} - \Pi)$$

$$E_t^{IS} \approx E_t^{IS}\big|_{ss} + \left.\frac{\partial E_t^{IS}}{\partial \xi_{t+1}}\right|_{ss} E_t(\xi_{t+1} - 1) + \left.\frac{\partial E_t^{IS}}{\partial c_{t+1}}\right|_{ss} E_t(c_{t+1} - c) + \left.\frac{\partial E_t^{IS}}{\partial \Pi_{t+1}}\right|_{ss} E_t(\Pi_{t+1} - \Pi)$$

where $|_{ss}$ indicates expressions evaluated at steady state. This together with (43), (44), and

$$E_t(z_{t+1} - 1) = \rho_z(z_t - 1)$$

$$E_t(\xi_{t+1} - 1) = \rho_\xi(\xi_t - 1)$$

delivers the expectations functions consistent with the approximated policy functions

$$\begin{aligned}
\alpha_0^1 &= \beta c^{-\sigma}\theta(\Pi - 1)\Pi \\
\alpha_1^1 &= \beta\theta\rho_z\left[c^{-\sigma}(2\Pi - 1)\delta_{\Pi z} - \sigma c^{-\sigma-1}(\Pi - 1)\Pi\delta_{cz}\right] \\
\alpha_2^1 &= \beta\theta\rho_\xi\left[c^{-\sigma}(2\Pi - 1)\delta_{\Pi\xi} - \sigma(\Pi - 1)\Pi\left(c^{-\sigma} + c^{-\sigma-1}\delta_{c\xi}\right)\right] \\
\alpha_0^2 &= \tfrac{\beta c^{-\sigma}}{\Pi} \\
\alpha_1^2 &= -\tfrac{\beta\rho_z}{\Pi}\left[\sigma c^{-\sigma-1}\delta_{cz} + \tfrac{c^{-\sigma}}{\Pi}\delta_{\Pi z}\right] \\
\alpha_2^2 &= -\tfrac{\beta\rho_\xi}{\Pi}\left[\sigma c^{-\sigma} + \sigma c^{-\sigma-1}\delta_{c\xi} + \tfrac{c^{-\sigma}}{\Pi}\delta_{\Pi\xi}\right]
\end{aligned}$$

where variables without time subscript denote steady state values. We iterate on the expectations functions until the maximum absolute change in the approximated policy functions drops below the square root of machine precision, i.e., approximately $1.49 \cdot 10^{-8}$.

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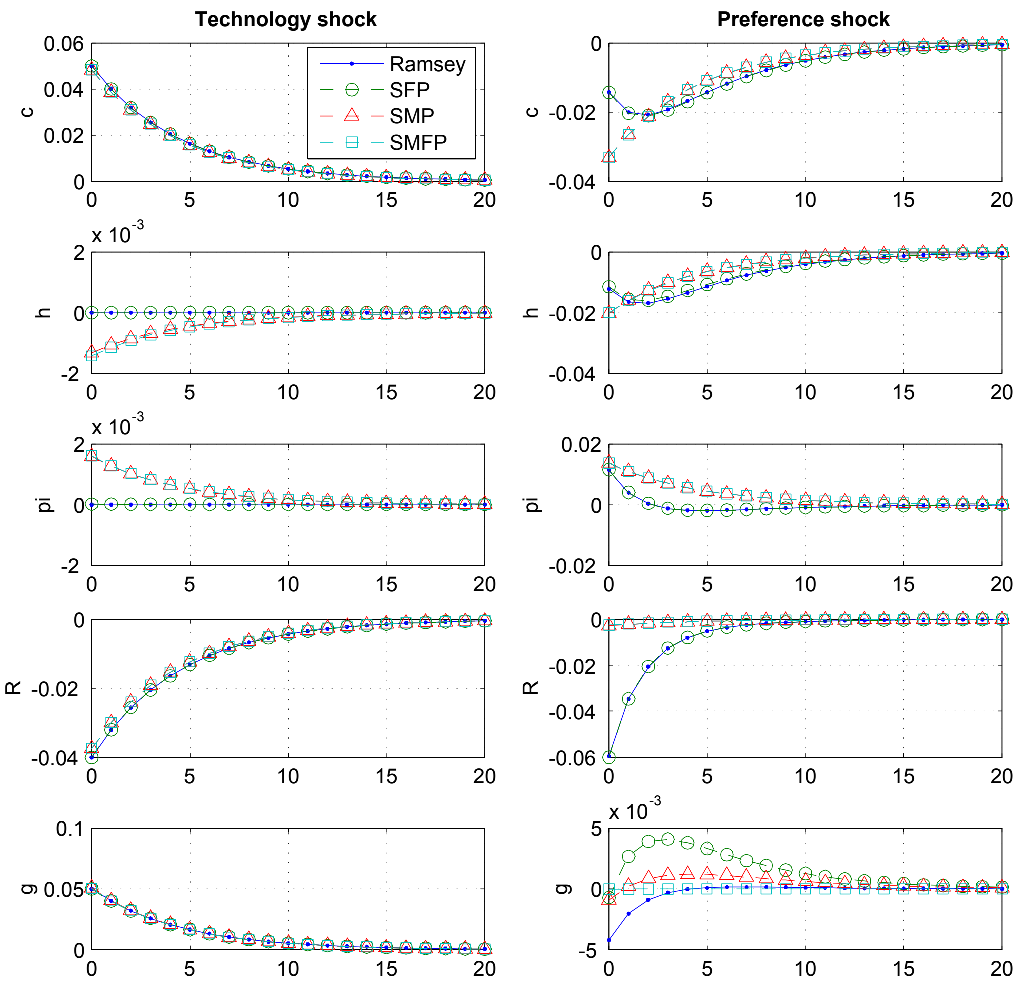

Figure 1: Impulse responses (baseline calibration)

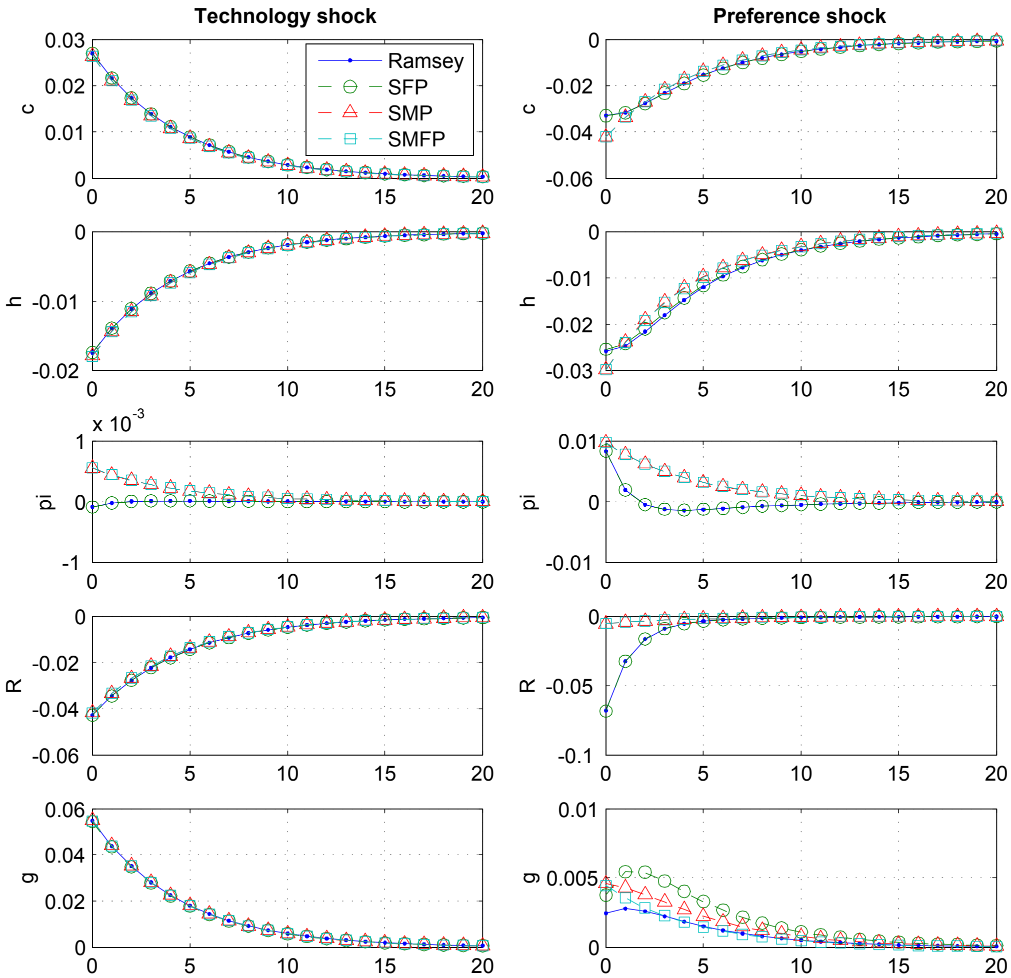

Figure 2: Impulse responses (higher risk aversion: $\sigma = 2$)

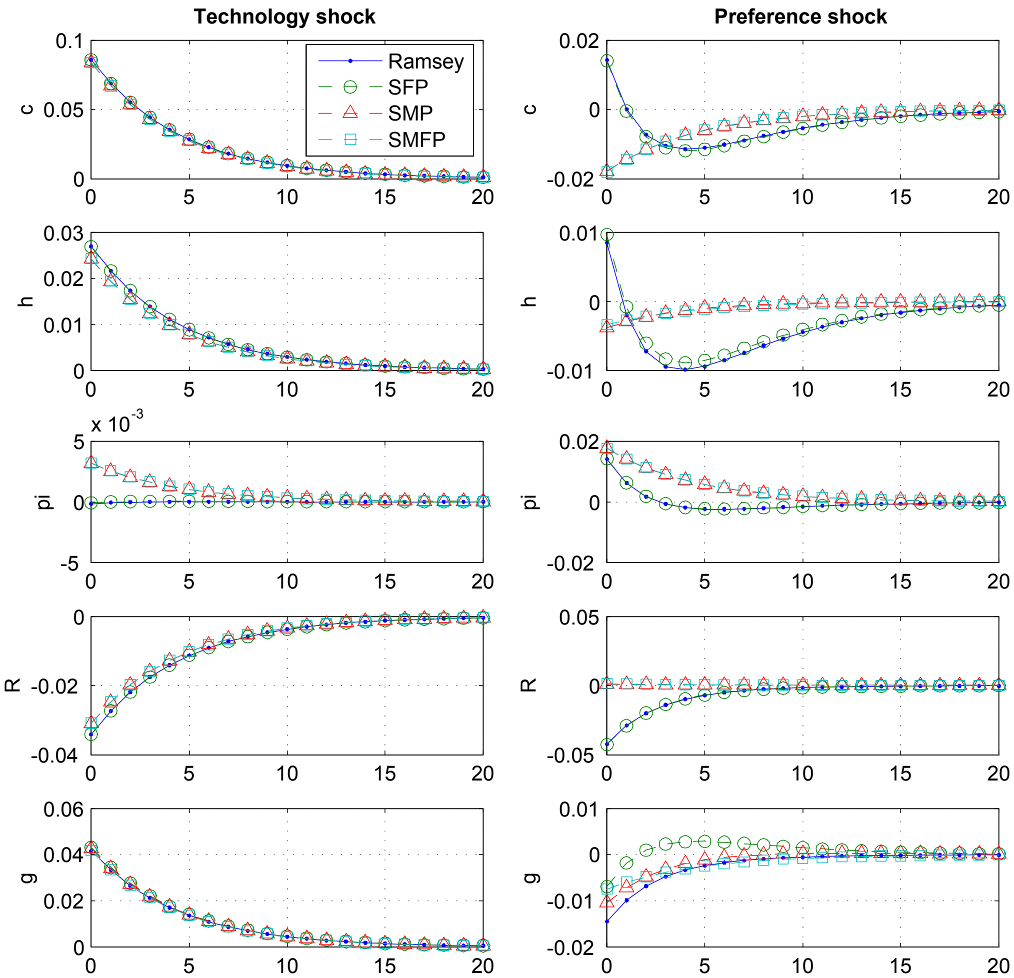

Figure 3: Impulse responses (lower risk aversion: $\sigma = 1/2$)