Distortionary fiscal policy and monetary policy goals[1]

Klaus Adam[2] Roberto M. Billi[3]

February 23, 2010

[1]We thank seminar participants at the Federal Reserve Bank of Kansas City for helpful comments. The views expressed herein are solely those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Kansas City or the Federal Reserve System.

[2]Mannheim University, Department of Economics, L7, 3-5, 68131 Mannheim, Germany (and CEPR, London), email: adam@uni-mannheim.de

[3]Federal Reserve Bank of Kansas City, 1 Memorial Drive, Kansas City, MO 64198, United States, email: roberto.billi@kc.frb.org

Abstract

We study interactions between monetary policy, which sets nominal interest rates, and fiscal policy, which levies distortionary income taxes to finance public goods, in a standard, sticky-price economy with monopolistic competition. Policymakers' inability to commit in advance to future policies gives rise to excessive inflation and excessive public spending, resulting in welfare losses equivalent to several percent of consumption each period. We show how appointing a conservative monetary authority, which dislikes inflation more than society does, can considerably reduce these welfare losse and that optimally the monetary authority is predominatly concerned about inflation. Full conservatism, i.e., exclusive concern about inflation, entirely eliminates the welfare losses from discretionary monetary and fiscal policymaking, provided monetary policy is determined after fiscal policy each period. Full conservatism, however, is severely suboptimal when monetary policy is determined simultaneously with fiscal policy or before fiscal policy each period.

Keywords: discretion, Nash and Stackelberg equilibria, policy biases, sequential non-cooperative policy games

JEL classification: E52, E62, E63

1 Introduction

The problem of designing institutional frameworks that cope best with discretionary behavior of policymakers has received much attention following the seminal work of Kydland and Prescott (1977) and of Barro and Gordon (1983). In particular, to overcome the inflationary bias caused by discretionary conduct of monetary policy, Rogoff (1985) proposed appointing a "conservative" central banker, who dislikes inflation more than society does.

More recently, Adam and Billi (2008) have shown inflation conservatism à la Rogoff also to be desirable in a setting with discretionary fiscal policy: besides overcoming the inflationary bias, monetary conservatism can also eliminate the public-spending bias stemming from discretionary public spending. But an unsatisfactory aspect of the analysis is the assumed availability of lump-sum taxes, which contrasts with the observation that governments must typically rely on distortionary tax instruments to raise revenue. Previous research, therefore, ignored an important source of economic distortions associated with the discretionary conduct of fiscal policy.

To address this shortcoming, this paper studies the interactions between discretionary monetary and fiscal policy in a setting with distortionary taxes. Monetary policy sets nominal interest rates and fiscal policy provides public goods, which are financed with a labor-income tax that distorts labor-supply decisions. We conduct the analysis in a dynamic, general-equilibrium model, with monopolistic competition and nominal rigidities. The presence of monopoly power and distortionary income taxes causes output to fall below its first-best level and provides discretionary policymakers an incentive to stimulate output.

We show analytically that discretionary fiscal policy gives rise to a public-spending bias when prices are stable, while discretionary monetary policy gives rise to an inflationary bias. In our numerical analysis we find these policy biases to be quantitatively important and also an order of magnitude larger than in a setting with lump-sum taxes. This is so because distortionary labor-income taxes amplify the effects of discretionary fiscal policy in a vicious circle. A higher level of public spending requires higher taxes, which depress labor supply and output. This in turn increases further the incentives for discretionary public spending. As a consequence, also the welfare loss is found to be much larger than with lump-sum taxes and is equivalent to a loss of several percent of consumption each period. This finding holds true even when abstracting from the welfare costs of inflation.

In our general-equilibrium model of the economy, we then study the equilibrium outcomes of a non-cooperative game between a discretionary fiscal authority, which maximizes social welfare, and a discretionary monetary authority, which dislikes inflation more than society does. We show that appointing such an inflation-conservative monetary authority can greatly reduce the welfare loss due to discretionary policymaking and that a high degree of monetary conservatism is optimal across a very wide range of model parameterizations. Monetary conservatism can even entirely eliminate the steady-state distortions due to discretionary monetary *and* fiscal policy when monetary policy can impose discipline on public spending by moving after fiscal policy each period. Although a high degree of monetary conservatism is found to be optimal for any timing assumption on the sequence of moves between monetary an fiscal policy, exclusive focus on inflation on the side of the monetary authority is optimal only when monetary policy moves after fiscal policy each period. Otherwise, moving from the optimal (and high) degree of conservatism to full conservatism gives rise to large welfare losses. As we show, after some point the welfare gains from further inflation reductions are outweighed by the increasing distortions in fiscal policy decisions that result from reduced inflation.

The second section describes the model. The third section explains the policy biases. The fourth section quantifies them. And the fifth section quantifies the effects of inflation conservatism. Technical details are in the appendix.

2 The model

This section describes a sticky-price economy with monopolistic competition and separate monetary and fiscal policy authorities. The setting is based on the model used in Adam and Billi (2008), but relaxes the strong assumption of lump-sum taxes by considering instead distortionary labor-income taxes. We first describe the private sector and the government and thereafter define a private-sector equilibrium.

2.1 Private sector

There is a continuum of identical households with preferences given by

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

where c_t is consumption of an aggregate consumption good, $h_t \in (0,1)$ is labor effort, g_t is public-goods provision by the government in the form of aggregate consumption goods, and $\beta \in (0,1)$ is the discount factor. Utility is separable in c, h, and g. In addition, $u_c > 0$, $u_{cc} < 0$, $u_h < 0$, $u_{hh} \leq 0$, $u_g > 0$, and $u_{gg} < 0$. Furthermore, $\left|\frac{cu_{cc}}{u_c}\right|$ and $\left|\frac{hu_{hh}}{u_h}\right|$ are bounded.

Each household produces a differentiated intermediate good. Demand for this good is $y_t d(\widetilde{P}_t/P_t)$, where y_t is (private and public) demand for the aggregate good, and $\widetilde{P}_t/P_t$ is the relative price of the intermediate good compared with the aggregate good. The demand function $d(\cdot)$ satisfies $d(1) = 1$ and $d'(1) = \eta$, where $\eta < -1$ is the price elasticity of demand for the different goods. The demand function is consistent with optimizing behavior when private and public consumption goods are a Dixit-Stiglitz aggregate of the goods produced by different households. Each household chooses $\widetilde{P}_t$, and hires labor effort $\widetilde{h}_t$ to satisfy the resulting product demand, i.e.,

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

As in Rotemberg (1982), sluggish nominal-price adjustment is described by quadraticresource costs of adjusting prices according to

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

where $\theta > 0$ indexes the degree of price stickiness.[1]

Households' budget constraint is

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

where $R_t \geq 1$ is the gross nominal interest rate.[2] B_t are private-issued nominal bonds paying $R_t B_t$ in period $t+1$, w_t is the real wage paid in a competitive labor market, and τ_t is a (distortionary) labor-income tax rate. Instead of labor-income taxes, we could have considered taxes on total income (profits and labor income) or consumption taxes. As is well known, consumption taxes are equivalent to having a labor-income tax together with a lump-sum tax on profits. We decided to analyze the most distortionary tax system, so we consider labor-income taxes.

Finally, the no-Ponzi-scheme constraint is

$$\lim_{j\to\infty}\prod_{i=0}^{t+j-1}\frac{1}{R_i}B_{t+j} \geq 0. \quad (4)$$

Based on these assumptions, households' problem consists of choosing $\{c_t, h_t, \widetilde{h}_t, \widetilde{P}_t, B_t\}_{t=0}^{\infty}$, so to maximize (1), subject to (2)-(4), and taking $\{y_t, P_t, w_t, R_t, g_t, \tau_t\}_{t=0}^{\infty}$ as given. The first-

[1] Using the Calvo approach to describe nominal rigidities would complicate considerably the analysis, because then price dispersion becomes an endogenous state variable.

[2] We abstract from money holdings and seigniorage by considering a "cashless-limit" economy à la Woodford (1998). Hence, money only imposes a zero lower bound on nominal interest rates, i.e., $R_t - 1 \geq 0$ for all t.

order conditions of this problem are (2)-(4) holding with equality, and

$$\begin{aligned}-\frac{u_{ht}}{u_{ct}} =& w_t(1-\tau_t) \qquad (5)\\ \frac{u_{ct}}{R_t} =& \beta\frac{u_{ct+1}}{\Pi_{t+1}}\\ 0 =& u_{ct}\left[y_t d(r_t) + r_t y_t d'(r_t) - \frac{w_t}{z_t} y_t d'(r_t) - \theta\left(\Pi_t\frac{r_t}{r_{t-1}} - 1\right)\frac{\Pi_t}{r_{t-1}}\right]\\ &+ \beta\theta u_{ct+1}\left(\frac{r_{t+1}}{r_t}\Pi_{t+1} - 1\right)\frac{r_{t+1}}{r_t^2}\Pi_{t+1},\end{aligned}$$

where $r_t \equiv \frac{\widetilde{P}_t}{P_t}$ denotes the relative price and $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ the gross inflation rate. Equation (5) shows that labor-income taxes distort the marginal rate of substitution between leisure and consumption.

In addition to the equations above, a transversality condition, $\lim_{j\to\infty}\left(\beta^{t+j}u_{ct+j}B_{t+j}/P_{t+j}\right) = 0$, has to hold at all contingencies. We assume private-issued bonds are in zero aggregate net supply, so the transversality condition is always satisfied. The same applies to the no-Ponzi-scheme constraint (4).

2.2 Government

The government consists of two authorities, namely a monetary authority controlling short-term nominal interest rates R_t and a fiscal authority determining public-goods provision g_t and income-tax rates τ_t in each period t.[3]

The government cannot credibly commit in advance to future policies or to repay debt in the future, i.e., it operates under full discretion. As a consequence, public-goods provision must be financed with current taxes only and the government's balanced-budget constraint is

$$\tau_t w_t h_t = g_t. \qquad (6)$$

[3] Of course, monetary policy controls the nominal interest rate by adjusting the money supply. This requires that it owns a stock of private bonds to perform the necessary open market operations. Since we consider a cashless-limit economy, as in Woodford (1998), the required stock of bonds is infinitesimally small, allowing us to assume that monetary policy controls directly nominal interest rates.

As a benchmark, we will also consider a Ramsey equilibrium in which the government commits in advance to future policies and thereby could credibly promise to repay debt. Yet to facilitate comparison, we will still impose the balanced-budget constraint (6) and set the initial level of government-issued debt equal to zero.[4]

2.3 Private-sector equilibrium

We consider a symmetric price-setting equilibrium in which the relative price r_t is equal to 1 for all t. It follows that, the first-order conditions describing households' behavior can be condensed into a price-setting equation, i.e., a Phillips curve

$$u_{ct}(\Pi_t - 1)\Pi_t = \frac{u_{ct}h_t}{\theta}\left(1 + \eta + \eta\left(\frac{u_{ht}}{u_{ct}} - \frac{g_t}{h_t}\right)\right) + \beta u_{ct+1}(\Pi_{t+1} - 1)\Pi_{t+1}, \tag{7}$$

and a consumption-Euler equation

$$\frac{u_{ct}}{R_t} = \beta\frac{u_{ct+1}}{\Pi_{t+1}}. \tag{8}$$

Conveniently, the last two equations do not make reference to taxes and real wages. Rather these are determined by (5) and (6) which give

$$\tau_t = \frac{g_t}{g_t - h_t\frac{u_{ht}}{u_{ct}}} \tag{9}$$

$$w_t = \frac{g_t}{h_t} - \frac{u_{ht}}{u_{ct}}. \tag{10}$$

A private-sector equilibrium, therefore, consists of a plan $\{c_t, h_t, \Pi_t\}$ satisfying (7), (8), and a market-clearing condition (resource constraint)

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

taking policies $\{g_t, R_t \geq 1\}$ as given.[5]

[4] The absence of government-issued debt implies we abstract from monetary and fiscal interactions operating directly through the government's budget constraint, see Díaz-Giménez et al. (2008).

[5] The initial price level P_{-1} can be ignored, because it only normalizes the price-level path.

3 Policy regimes and biases

In this section, we study policy regimes with and without commitment to future policies and the associated equilibrium allocations. We start by studying the first-best allocation, which assumes policy commitment and abstracts from monopoly and tax distortions and nominal rigidities. We then study a Ramsey allocation, which accounts for monopoly distortions, nominal rigidities, and distortionary labor-income taxes. Finally, we relax the assumption of policy commitment and study allocations under sequential policymaking, taking into account all aforementioned distortions. We show that sequential-fiscal policy causes too much public spending, while sequential-monetary policy causes too much inflation.

3.1 First-best and Ramsey allocation

The first-best allocation, which abstracts from all distortions and commitment problems, satisfies in steady state the following condition:[6]

$$u_c = u_g = -u_h.$$

It is thus optimal to equate the marginal utility of private and public consumption to the marginal disutility of labor effort. This condition follows directly from the linearity of the production function and the preference structure. As we show next, the condition is no longer optimal when the distortions in the economy are taken into account even if policymakers can credibly commit.

The Ramsey allocation, which accounts for tax and monopoly distortions and nominal rigidities, must satisfy the implementability constraints (7) and (8) and the resource constraint

[6]The condition follows from solving $\max_{\{c_t,h_t,g_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, g_t)$, subject to (11) with $\theta = 0$ and from imposing on the resulting first-order conditions a steady-state restriction.

(11). It solves the following problem:

$$\max_{\{c_t, h_t, \Pi_t, R_t \geq 1, g_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, g_t) \tag{12}$$

subject to (7), (8), and (11) for all t.

Note, the Ramsey allocation still allows for advance-policy commitment. The first-order conditions of this problem show that the Ramsey steady state satisfies

$$\Pi = 1 \quad \text{and} \quad R = \frac{1}{\beta}, \tag{13}$$

as well as marginal conditions

$$-u_h < u_g \tag{14}$$

$$-u_h = \left(\frac{1+\eta}{\eta} - \frac{g}{h} \right) u_c. \tag{15}$$

See appendix A.1 for derivations. Equation (13) shows that it is optimal to achieve price stability. In addition, (14) shows that public spending in the Ramsey allocation falls short of its first-best level. This is optimal because public spending increases taxes and thereby the wedge between the marginal utility of private consumption and the marginal disutility of labor effort, see equation (15). This wedge has two components. The first component is due to the monopoly power of firms, which causes real wages to fall short of their marginal product.[7] The second component—which is missing in the setting of Adam and Billi (2008)—stems from distortionary labor-income taxes levied to finance public spending. Reducing public spending below the first-best level lowers taxes and reduces this wedge.

3.2 Sequential-policy regimes

We now study separate monetary and fiscal authorities that cannot commit in advance to future policies and, instead, decide policies sequentially at the time of implementation. We

[7] Equations (10) and (15) imply $w = (1+\eta)/\eta < 1$.

derive a policy-reaction function for each authority. To facilitate the exposition, we assume each authority takes the current policy of the other authority and all future private-sector and policy decisions as given. We then verify the rationality of this assumption and define a sequential-policy equilibrium.

3.2.1 Sequential-fiscal policy: spending bias

Based on the assumptions made, the fiscal authority's problem in period t is

$$\max_{(c_t,h_t,\Pi_t,g_t)} \sum_{j=0}^{\infty} \beta^j u(c_{t+j}, h_{t+j}, g_{t+j}) \tag{16}$$

subject to (7), (8), and (11) for all t

and $\{c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j-1} \geq 1, g_{t+j}\}$ given for $j \geq 1$.

In this problem the fiscal authority takes current monetary policy R_t and future decisions as given. Eliminating Lagrange multipliers from the first-order conditions of the problem delivers a *fiscal-reaction function*

$$u_{gt} = -u_{ht} \frac{2\Pi_t - 1 - \eta(\Pi_t - 1)}{2\Pi_t - 1 - (\Pi_t - 1)\left(1 + \eta + \eta\frac{u_{ht}}{u_{ct}} + \eta h_t \frac{u_{hht}}{u_{ct}}\right)}. \tag{FRF}$$

See appendix A.2 for the derivation. This FRF determines (implicitly) the optimal level of public-goods provision g_t in each period t under sequential-fiscal policy.

To study the implications of sequential-fiscal policy, consider a steady state in which policy achieves price stability ($\Pi = 1$) as in the Ramsey allocation. The FRF then simplifies to

$$u_g = -u_h. \tag{17}$$

Under price stability, fiscal policy thus equates the marginal utility of public consumption to the marginal disutility of labor effort. Such behavior is consistent with the first-best allocation, but suboptimal in the presence of tax and monopoly distortions that require reducing public spending below its first-best level, see the Ramsey optimality condition (14). Sequential-fiscal policy, therefore, causes a "spending bias" as summarized in the following proposition:

Proposition 1 *Sequential-fiscal policy under price stability causes a spending bias.*

The intuition for this finding is as follows. Since fiscal policy takes future allocations and the monetary policy decision R_t as given, the Euler equation (8) implies that private consumption is equally perceived as given. A discretionary fiscal policymaker thus perceives to affect labor supply one-for-one with public spending and to have no distortionary effects on private consumption, which implies rule (17) is optimal. But in equilibrium future spending and tax decisions do affect future labor supply and future private consumption. Low future consumption then adversely affects current consumption via the anticipation effects implicit in the Euler equation. But a discretionary policymaker does not perceive the effects that current policy have on past decisions of forward-looking households.

In general when price stability is not achieved, the fiscal policymaker also takes into account that any additional public spending increases inflation and that this involves non-zero marginal resource costs.[8] These marginal resource costs of inflation therefore lead to the more general expression FRF.

3.2.2 Sequential-monetary policy: inflation bias

The monetary authority's problem in period t is

$$\max_{(c_t, h_t, \Pi_t, R_t \geq 1)} \sum_{j=0}^{\infty} \beta^j u(c_{t+j}, h_{t+j}, g_{t+j}) \tag{18}$$

subject to (7), (8), and (11) for all t

and $\{c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j} \geq 1, g_{t+j-1}\}$ given for $j \geq 1$.

In this problem the monetary authority takes current fiscal policy g_t and future decisions as given. Eliminating Lagrange multipliers from the first-order conditions of the problem

[8] Recall that fiscal policy perceives output to move one-for-one with public spending, because it perceives private consumption as given. Therefore public spending implies an increase in wages and, via the Phillips curve (7), an increase in inflation.

delivers a *monetary-reaction function*

$$
\begin{aligned}
&-\frac{u_{ct}}{u_{ht}}\left(\eta\left(\Pi_t-1\right)-\Pi_t\right)-\left(\Pi_t-1\right)\eta\left(1+h_t\frac{u_{hht}}{u_{ht}}\right)\\
&+2\Pi_t-1-\frac{u_{cct}}{u_{ct}}\left(\Pi_t-1\right)\left(\theta(\Pi_t-1)\Pi_t-h_t\left(1+\eta-\eta\frac{g_t}{h_t}\right)\right)=0.
\end{aligned}
\tag{MRF}
$$

Appendix A.3 shows the derivation. This MRF determines (implicitly) the optimal level of nominal interest rates R_t in each period t under sequential-monetary policy.

Consider again a steady state in which policy achieves price stability ($\Pi = 1$) as in the Ramsey allocation. MRF then simplifies to

$$u_c = -u_h.$$

Under price stability, monetary policy thus equates the marginal utility of private consumption to the marginal disutility of labor effort. Again such behavior is consistent with the first-best allocation and suboptimal in the presence of monopoly and tax distortions, see the Ramsey optimality condition (15). Monetary policy thus seeks to increase output above the Ramsey steady state and the MRF is actually inconsistent with price stability. Therefore sequential-monetary policy causes an "inflation bias," as in the standard case with exogenous fiscal policy studied, for example, in Svensson (1997) and in Walsh (1995). This result is captured in the following proposition, which is formally proven in appendix A.4:

Proposition 2 *Sequential-monetary policy causes an inflationary bias: the steady-state gross inflation rate* Π *is strictly bigger than* 1*, provided the discount factor* β *is sufficiently close to* 1*.*

3.2.3 Sequential-policy (SP) equilibrium

We now define a sequential-policy equilibrium. We start by verifying the rationality of the assumption we made that each authority can take the current policy of the other authority and all future decisions as given. When solving the fiscal authority's problem (16) and the monetary authority's problem (18), we observe (7), (8), and (11) depend on current and future decisions only.[9] This observation suggests the existence of an equilibrium in which indeed current policy is independent of past decisions and, in turn, future policy is independent of current decisions. Also the resulting policy-reaction functions FRF and MRF then depend on current decisions only.

Based on these considerations, we can formally define a Markov-perfect Nash equilibrium under sequential monetary and fiscal policy.[10] In such a Nash equilibrium, the monetary and fiscal authorities decide their respective policies simultaneously in each period with each authority deciding policy based on its own policy-reaction function:

Definition 3 (SP) *A Markov-perfect Nash equilibrium under sequential monetary and fiscal policy is a steady state* $\{c, h, \Pi, R \geq 1, g\}$ *satisfying (7), (8), (11), FRF, and MRF.*

Importantly, the assumption of simultaneous-policy decisions does not matter for the equilibrium outcome. This is because the monetary and fiscal authorities share the same objective function.[11] In section 5, where the two authorities pursue different objectives due to monetary conservatism, the (within-period) timing of policy decisions will start to matter for the equilibrium outcome.

[9] There are no state variables in the model.

[10] The concept of Markov-perfect equilibrium, as defined in Maskin and Tirole (2001), figures prominently in applied game theory. See for example Klein, Krusell, and Ríos-Rull (2008).

[11] Consider a Stackelberg game in which one authority decides before the other each period. Then, provided both players share the same policy objective, the follower's policy-reaction function does not need to be imposed as a constraint in the leader's problem. Rather, it can be derived directly from the leader's first-order conditions.

4 How much inflation is optimal?

We have shown sequential-fiscal policy spends too much on public goods, while sequential-monetary policy gives rise to an inflation bias. In this section, we quantify these policy biases. As a point of reference, we first describe an optimal-inflation regime in which the monetary authority is capable of advance-policy commitment, but fiscal policy follows the reaction function FRF. We then determine the equilibrium outcome without monetary and fiscal policy commitment in a calibrated version of the model. Comparing the outcome in this latter setting with that in the optimal-inflation regime, we argue that installing an inflation-conservative central bank is desirable for society as it may result in large welfare gains.

4.1 Optimal-inflation (OI) regime

This section considers an intermediate policy problem in which the monetary authority can commit in advance to future policies, while the fiscal authority determines its actions according to the reaction function FRF. This policy problem is of interest because it allows to determine the welfare-optimal inflation rate in the presence of discretionary fiscal policy. The policy problem is

$$\max_{\{c_t, h_t, \Pi_t, R_t \geq 1, g_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, g_t) \tag{OI}$$

subject to (7), (8), (11), and FRF for all t.

And we refer to it as the optimal-inflation (OI) regime. In this regime, the monetary authority sets an equilibrium inflation rate which accounts for the fiscal authority's inability to commit in advance to future policies.[12] It contrasts with the sequential-policy (SP) regime, described in the previous section, which also accounts for the monetary authority's inability to

[12] In steady state, equation (8) implies $\Pi = \beta R$. Thereby the monetary authority, by setting the gross nominal interest rate R, determines the gross inflation rate Π.

commit. If inflation in the OI regime lies below that emerging in the SP regime, this suggests inflation conservatism is desirable to the extent that it is effective in lowering the equilibrium inflation rate in the economy.

4.2 Calibration

We now turn to numerical results. We calibrate the model as in Adam and Billi (2008), so to make the results comparable. Accordingly, household preferences are specified as

$$u(c_t, h_t, g_t) = \log(c_t) - \omega_h \frac{h_t^{1+\varphi}}{1+\varphi} + \omega_g \log(g_t), \tag{19}$$

where $\omega_h > 0$, $\omega_g \geq 0$, and $\varphi \geq 0$.[13]

The baseline parameter values are shown in table 1. In the baseline, the discount factor β is equal to 0.9913 quarterly, which implies a real interest rate of 3.5 percent annually. The price elasticity of demand η is equal to -6, so the mark-up of prices over marginal costs is 20 percent.[14] The degree of price stickiness θ is equal to 17.5, so the log-linearized version of Phillips curve (7) is consistent with that in Schmitt-Grohé and Uribe (2004). And the labor-supply elasticity φ^{-1} is equal to 1. In addition, we set the utility weights ω_h and ω_g such that in the Ramsey allocation agents work 20 percent of their time (h equal to 0.2) and spend 20 percent of output on public goods (g equal to 0.04).[15] Thereby the labor-income tax rate τ is 24 percent.

We tested the robustness of the numerical results across a wide range of parameter values, and by using in the numerical procedure different starting values for the allocation. As we will show below, the results are found to be robust.[16]

[13] This specification is consistent with balanced growth.

[14] The mark-up μ is given by $1 + \mu = \eta / (1 + \eta)$.

[15] We set the utility weights using (47) and (51) in appendix A.5.

[16] To make the Ramsey allocation invariant to changes in parameter values, we adjust the utility weights ω_h and ω_g. Using different starting values for the allocation, we did not encounter multiplicities in the equilibrium allocation under any of the policy regimes.

4.3 Quantifying policy biases

The effects of sequential policy under the baseline parameterization are shown in table 2. The second column shows the effects on the equilibrium allocation, i.e., on private consumption c, hours worked h, gross inflation Π, and public goods g. These effects are measured as the difference from the Ramsey allocation.[17] The third column shows the labor-income tax rate. And the last column shows the welfare loss as measured by the permanent loss in private consumption compared with the Ramsey allocation.[18]

The effects in the SP regime are shown in the first row of table 2. In such a regime, the inflation bias is found to be sizable. In fact, inflation is roughly 4.5 percent higher than in the Ramsey allocation. Also the spending bias is found to be sizable, with spending on public goods roughly 14 percent higher than in the Ramsey allocation. Overall, therefore, the welfare loss due to sequential policy is big, and equivalent to foregoing more than 8 percent of private consumption each period compared with the Ramsey allocation. Although about 80 percent of the welfare loss is due to the resource costs of inflation, the remaining 20 percent of the loss is due to distorted allocations between hours worked, private consumption, and public goods. The latter 20 percent of the loss is equivalent to foregoing 1.6 percent of consumption each period. Therefore the welfare losses is large by conventional standards even when abstracting from the resource costs of inflation.

The effects in the OI regime are shown in the second row of table 2. In this regime, the inflation bias remains sizable, but is less than half of that in the SP regime. The fact that the optimal inflation rate in the OI regime is below the inflation bias emerging in the SP regime indicates that indeed inflation conservatism would be desirable for society. Moreover,

[17] In the Ramsey allocation $c = 0.16$, $h = 0.2$, $\Pi = 1$, $g = 0.04$, and $\tau = 0.24$.

[18] More specifically, the welfare loss is measured as the permanent reduction in private consumption that would make welfare in the Ramsey allocation equivalent to welfare in the policy regime considered. See appendix A.6.

the welfare loss in the OI regime is about one half of that in the SP regime, which suggests that inflation conservatism may result in large welfare gains. Interestingly, the fiscal spending bias increases roughly by a factor of three compared to the SP regime. This is because lower inflation reduces the fiscal authority's perceived costs of public spending, as discussed before.[19] Despite the high level of public spending, hours worked in the OI regime are roughly the same as in the Ramsey allocation. Now only about 30 percent of the welfare loss is due to the resource costs of inflation, while the remaining 70 percent of the loss is largely due to the distortion in the allocation between private consumption and public goods. The latter 70 percent of the loss now amounts to foregoing 3.3 percent of consumption each period, which indeed is large by conventional standards.

These findings are robust across a wide range of parameter values. The last two columns of table 3 show that the potential welfare gains from inflation conservatism remain sizable across a wide range of model parameterizations. They disappear, however, in the limiting cases when prices become flexible (θ sufficiently close to zero), when goods markets become competitive (η sufficiently low), and when labor supply becomes inelastic (φ sufficiently high). Still, the optimal inflation rate in the OI regime lies below that in the SP regime for all the parameterizations, see the second column of table 3. This suggests that inflation conservatism remains desirable across a wide range of model parameterizations.

5 Conservative monetary authority

The previous section has shown that lowering inflation below the outcome emerging with sequential monetary and fiscal policy is highly desirable in welfare terms. In this section, we introduce an inflation-conservative monetary authority and asses to what extent inflation conservatism can deliver these welfare gains when both policymakers continue to determine

[19] This effect can be shown analytically in a setting in which taxes are lump sum, see Adam and Billi (2008).

policy sequentially. We consider three policy regimes, namely regimes in which monetary policy is decided before, simultaneously, or after fiscal policy within each period. We show that inflation conservatism is particularly desirable when fiscal policy is decided before monetary policy as it is then possible to recover the Ramsey steady state, despite both policymakers acting sequentially.

5.1 Inflation conservatism

As in Rogoff (1985) and in Adam and Billi (2008), we consider a sequential-monetary authority that not only cares about society's welfare, but also dislikes inflation directly. We model this by replacing the monetary authority's objective in each period t with a more general, inflation-conservative objective

$$(1-\alpha)u(c_t, h_t, g_t) - \alpha\frac{(\Pi_t - 1)^2}{2}, \tag{20}$$

where $\alpha \in [0, 1]$ measures the degree of the monetary authority's inflation conservatism. When α is equal to zero the monetary authority cares about society's welfare only, as assumed in the analysis so far. When α is strictly bigger than zero the monetary authority dislikes inflation more than suggested by social preferences, and as α approaches 1 the monetary authority starts to become exclusively concerned about inflation.

The fiscal authority continues to be concerned about social welfare only, i.e., the objective of the fiscal authority remains unchanged. With monetary and fiscal authorities no longer pursuing the same policy objective, the (within-period) timing of policy decisions now matters for the equilibrium outcome. Therefore we consider a Nash equilibrium and also Stackelberg equilibria with monetary and fiscal leadership.

5.2 Nash equilibrium

We start by considering the policy regime in which the monetary and fiscal authorities decide policies simultaneously each period. In such a Nash regime, the fiscal authority's problem remains unchanged and continues to take the monetary policy decision as given. Fiscal behavior thus continues to be described by the reaction function FRF. However, the monetary authority's problem in period t is now given by

$$\max_{(c_t,h_t,\Pi_t,R_t\geq 1)} \sum_{j=0}^{\infty} \beta^j \left[(1-\alpha)u(c_{t+j},h_{t+j},g_{t+j}) - \alpha\frac{(\Pi_{t+j}-1)^2}{2}\right] \tag{21}$$

subject to (7), (8), and (11) for all t

and $\{c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j} \geq 1, g_{t+j-1}\}$ given for $j \geq 1$.

In this problem the monetary authority still takes current fiscal policy g_t and future decisions as given. Eliminating Lagrange multipliers from the first-order conditions of the problem delivers a *conservative monetary-reaction function*

$$\begin{aligned} &-\frac{u_{ct}}{u_{ht}}\left(\eta\left(\Pi_t-1\right)-\Pi_t\right)-\left(\Pi_t-1\right)\eta\left(1+h_t\frac{u_{hht}}{u_{ht}}\right) \\ &+\left[2\Pi_t-1-\frac{u_{cct}}{u_{ct}}(\Pi_t-1)\left(\theta(\Pi_t-1)\Pi_t-h_t\left(1+\eta-\eta\frac{g_t}{h_t}\right)\right)\right]\frac{(1-\alpha)\,\theta-\alpha\frac{1}{u_{ht}}}{(1-\alpha)\,\theta+\alpha\frac{1}{u_{ct}}}=0. \end{aligned} \tag{CMRF}$$

See appendix A.7 for the derivation. When α is equal to zero CMRF simplifies to MRF, which is the monetary-reaction function without inflation conservatism. As before, CMRF still depends on current decisions only. Therefore it continues to be rational to take the current policy of the other authority and all future decisions as given. We can then define a Markov-perfect Nash equilibrium with conservative monetary policy as follows:

Definition 4 (CSP-Nash) *A Markov-perfect Nash equilibrium with conservative and sequential monetary policy, sequential-fiscal policy, and simultaneous-policy decisions is a steady state* $\{c, h, \Pi, R \geq 1, g\}$ *satisfying (7), (8), (11), FRF, and CMRF.*

5.3 Stackelberg equilibria

We now consider Stackelberg equilibria where one of the policymakers decides before the other each period. We start by considering a setting with monetary leadership (ML). Again, since the fiscal authority takes monetary decisions as given, its policy problem remains unchanged and its optimal behavior is described by the reaction function FRF. The monetary authority, however, takes into account FRF as an additional constraint, and its problem in period t becomes

$$\max_{(c_t, h_t, \Pi_t, g_t, R_t \geq 1)} \sum_{j=0}^{\infty} \beta^j \left[(1-\alpha) u(c_{t+j}, h_{t+j}, g_{t+j}) - \alpha \frac{(\Pi_{t+j} - 1)^2}{2} \right] \quad (22)$$

subject to (7), (8), (11), and FRF for all t

and $\{c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j} \geq 1, g_{t+j}\}$ given for $j \geq 1$.

In this problem the monetary authority still takes future decisions as given, but now anticipates how its choices affect the current fiscal-policy decision. Eliminating Lagrange multipliers from the first-order conditions of the problem delivers a *conservative monetary-reaction function* under *monetary leadership*, which we denote as CMRF-ML. The resulting equilibrium definition then is the following:

Definition 5 (CSP-ML) *A Markov-perfect Stackelberg equilibrium with conservative and sequential monetary policy, sequential-fiscal policy, and monetary policy decided before fiscal policy is a steady state* $\{c, h, \Pi, R \geq 1, g\}$ *satisfying (7), (8), (11), FRF, and CMRF-ML.*

Next, consider the opposite setting with fiscal leadership (FL). Since the monetary authority decides second, it takes fiscal decisions as given. Therefore its reaction function continues to be CMRF, which needs to be imposed as a constraint on the fiscal authority's problem

$$\max_{(c_t, h_t, \Pi_t, g_t, R_t \geq 1)} \sum_{j=0}^{\infty} \beta^j u(c_{t+j}, h_{t+j}, g_{t+j}) \tag{23}$$

subject to (7), (8), (11), and CMRF for all t

and $\{c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j} \geq 1, g_{t+j}\}$ given for $j \geq 1$.

In this problem the fiscal authority still takes future decisions as given, but anticipates the within-period reaction of nominal interest rates R_t as implied by CMRF. Eliminating Lagrange multipliers from the first-order conditions of the problem delivers a *conservative fiscal-reaction function* under *fiscal leadership*, which we denote as CFRF-FL. The resulting Markov-perfect Stackelberg equilibrium is defined as follows:

Definition 6 (CSP-FL) *A Markov-perfect Stackelberg equilibrium with conservative and sequential monetary policy, sequential-fiscal policy, and fiscal policy decided before monetary policy is a steady state* $\{c, h, \Pi, R \geq 1, g\}$ *satisfying (7), (8), (11), CFRF-FL, and CMRF.*

5.4 Effects of inflation conservatism

We now discuss the different policy regimes and compare the effects of inflation conservatism. In the Nash and ML regimes, the fiscal authority's reaction function is given by FRF. As a consequence, welfare in these regimes cannot exceed that of the OI regime. The situation is different in the FL regime where the fiscal authority anticipates within each period the monetary authority's inflation conservatism. This regime allows monetary conservatism to discipline the behavior of the fiscal authority, and thereby welfare may end up higher than in the OI regime.

Using the baseline parameterization, figure 1 shows the welfare gain from inflation conservatism. The figure shows the consumption-equivalent welfare losses (vertical axis) in deviation from the Ramsey outcome as a function of the degree of inflation conservatism α (horizontal axis). Besides showing the outcome under the three different timing protocols, the figure also shows a solid-horizontal line that corresponds to the welfare loss in the OI regime.

In the Nash and ML regimes, welfare increases with the degree of inflation conservatism and a value of α just slightly below 1 recovers the level of welfare in the OI regime. But increasing α all the way to 1 causes a steep welfare loss relative to the OI regime, which shows that full inflation conservatism ($\alpha = 1$) is not optimal under these timing protocols. An explanation for this non-monotone effect is provided below.

Regarding the FL regime, welfare again increases with α, but now monotonically, and reaches the Ramsey-steady-state level as α is increased all the way to 1. With fiscal leadership, therefore, full inflation conservatism eliminates the steady-state distortions associated with lack of monetary *and* fiscal commitment.

Overall, figure 1 suggests that inflation conservatism is desirable, because then welfare is always higher, for all timing protocols and for all values of α. With monetary leadership and with simultaneous policy decisions, however, it is not optimal for monetary policy to be exclusively concerned about inflation stabilization ($\alpha = 1$). The reason for this finding can be uncovered by considering the allocational effects of different degrees of inflation conservatism under the different timing protocols.

Again using the baseline parameterization, figure 2 shows the effects of different degrees of inflation conservatism (horizontal axis) on the equilibrium outcomes. As shown, inflation conservatism unambiguously lowers the equilibrium inflation rate (lower-left panel) and hours worked (top-right panel). The latter effect occurs partly because lower inflation gives rise to lower resource costs.

The effects on the fiscal-spending bias (lower-right panel), however, depend crucially on whether the fiscal authority internalizes the monetary authority's direct reaction to inflation, i.e., on whether fiscal policy moves before monetary policy. Inflation conservatism reduces the fiscal-spending bias in the FL regime but increases it strongly in the Nash and ML regimes, which results in large welfare losses as α approaches 1.

This divergence in outcomes can be rationalized as follows. As explained above, inflation conservatism lowers the equilibrium inflation rate. As a result, it also lowers the marginal resource costs of inflation, so the perceived costs of additional inflation caused by additional public spending are equally lower. Therefore when fiscal policy takes monetary policy as given, as in the Nash and ML regimes, lower inflation induces the fiscal authority to increase public spending. But in the FL regime the fiscal authority anticipates that higher public spending will come at the cost of higher nominal interest rates, because the monetary authority will tighten monetary policy to partially offset a rise in inflation. The consumption Euler equation (8) then implies that the fiscal authority perceives that public spending crowds out private consumption in the current period. Indeed for α equal to 1 the fiscal authority anticipates that higher public spending lowers private consumption one-for-one, as monetary policy does not tolerate any inflation and any change in hours worked. Fiscal policy then correctly perceives the one-for-one trade-off between private consumption and public spending as implied by the production function. Therefore fiscal policy implements the Ramsey level of public spending even though it lacks the ability to commit to future policies.

Table 4 displays the optimal degree of inflation conservatism (α^{opt}) for the Nash and ML regimes and a wide range of model parameterizations. It shows that, independently from the precise parameter values, the central bank should predominantly be concerned about inflation in these regimes. At the same time, however, increasing monetary conservatism to the maximum degree ($\alpha = 1$) is severely suboptimal. As the last two columns table 4 show, such a move is typically associated with welfare losses that are equivalent to several percentage points of consumption each period. The findings from the baseline calibration are thus robust across many model parameterizations.

6 Conclusions

We study interactions between discretionary monetary and fiscal policymakers when monetary policy sets nominal interest rates and fiscal policy provides public goods that are financed with distortionary taxes. The welfare loss resulting from sequential policymaking is found to be equivalent to foregoing several percent of private consumption each period. This welfare loss, however, can be largely reduced and even eliminated by appointing a conservative monetary authority, who dislikes inflation more than society does.

A high degree of inflation conservatism is found to be optimal for any timing assumption on the sequence of moves in the non-cooperative game between monetary and fiscal policymakers. But it is suboptimal for the monetary authority to focus exclusively on inflation stabilization when the fiscal authority fails to anticipate that its policy decision affects the monetary authority's interest-rate decision. When such anticipation of policy interactions occurs, the monetary authority should focus exclusively on inflation stabilization. Full inflation conservatism then eliminates the steady-state distortions associated with lack of monetary *and* fiscal commitment.

References

Adam, K., and R. Billi (2008): "Monetary Conservatism and Fiscal Policy," *Journal of Monetary Economics*, 55, 1376–1388.

Barro, R., and D. B. Gordon (1983): "A Positive Theory of Monetary Policy in a Natural Rate Model," *Journal of Political Economy*, 91, 589–610.

Díaz-Giménez, J., G. Giovannetti, R. Marimon, and P. Teles (2008): "Nominal Debt as a Burden on Monetary Policy," *Review of Economic Dynamics*, 11, 493–514.

Klein, P., P. Krusell, and J.-V. Ríos-Rull (2008): "Time Consistent Public Policy," *Review of Economic Studies*, 75, 789–808.

Kydland, F. E., and E. C. Prescott (1977): "Rules Rather Than Discretion: The Inconsistency of Optimal Plans," *Journal of Political Economy*, 85, 473–492.

Maskin, E., and J. Tirole (2001): "Markov Perfect Equilibrium: I. Observable Actions," *Journal of Economic Theory*, 100, 191–219.

Rogoff, K. (1985): "The Optimal Degree of Commitment to an Intermediate Monetary Target," *Quarterly Journal of Economics*, 100(4), 1169–89.

Rotemberg, J. J. (1982): "Sticky Prices in the United States," *Journal of Political Economy*, 90, 1187–1211.

Schmitt-Grohé, S., and M. Uribe (2004): "Optimal Fiscal and Monetary Policy under Sticky Prices," *Journal of Economic Theory*, 114(2), 198–230.

Svensson, L. E. O. (1997): "Optimal Inflation Targets, 'Conservative' Central Banks, and Linear Inflation Contracts," *American Economic Review*, 87, 98–114.

Walsh, C. E. (1995): "Optimal Contracts for Central Bankers," *American Economic Review*, 85, 150–67.

Woodford, M. (1998): "Doing Without Money: Controlling Inflation in a Post-Monetary World," *Review of Economic Dynamics*, 1, 173–209.

A Appendix

A.1 Ramsey allocation

The Lagrangian of the Ramsey problem (12) is

$$\max_{\{c_t,h_t,\Pi_t,R_t,g_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \Bigg\{ u(c_t, h_t, g_t)$$
$$+ \gamma_t^1 \left[u_{ct}(\Pi_t - 1)\Pi_t - \frac{u_{ct} h_t}{\theta} \left(1 + \eta + \eta \left(\frac{u_{ht}}{u_{ct}} - \frac{g_t}{h_t}\right)\right) - \beta u_{ct+1}(\Pi_{t+1} - 1)\Pi_{t+1} \right]$$
$$+ \gamma_t^2 \left[\frac{u_{ct}}{R_t} - \beta \frac{u_{ct+1}}{\Pi_{t+1}} \right]$$
$$+ \gamma_t^3 \left[h_t - c_t - \frac{\theta}{2}(\Pi_t - 1)^2 - g_t \right] \Bigg\}.$$

The first-order conditions with respect to c_t, h_t, Π_t, R_t, and g_t, respectively, are

$$u_{ct} + \gamma_t^1 \left(u_{cct}(\Pi_t - 1)\Pi_t - \frac{u_{cct} h_t}{\theta} \left(1 + \eta - \eta \frac{g_t}{h_t}\right)\right)$$
$$-\gamma_{t-1}^1 u_{cct}(\Pi_t - 1)\Pi_t + \gamma_t^2 \frac{u_{cct}}{R_t} - \gamma_{t-1}^2 \frac{u_{cct}}{\Pi_t} - \gamma_t^3 = 0 \tag{24}$$
$$u_{ht} - \gamma_t^1 \frac{u_{ct}}{\theta} \left(1 + \eta + \eta \left(\frac{u_{ht}}{u_{ct}} + h_t \frac{u_{hht}}{u_{ct}}\right)\right) + \gamma_t^3 = 0 \tag{25}$$
$$\left(\gamma_t^1 - \gamma_{t-1}^1\right) u_{ct}(2\Pi_t - 1) + \gamma_{t-1}^2 \frac{u_{ct}}{\Pi_t^2} - \gamma_t^3 \theta(\Pi_t - 1) = 0 \tag{26}$$
$$-\gamma_t^2 \frac{u_{ct}}{R_t^2} = 0 \tag{27}$$
$$u_{gt} + \gamma_t^1 \frac{u_{ct}}{\theta}\eta - \gamma_t^3 = 0, \tag{28}$$

where $\gamma_{-1}^j = 0$ for $j = 1, 2$.

We recover the steady state by dropping time subscripts. Then condition (27), $u_{ct} > 0$, and $R_t \geq 1$ imply

$$\gamma^2 = 0.$$

This and (26) give

$$\Pi = 1.$$

From (8) then follows

$$R = \frac{1}{\beta}.$$

The last two results deliver (13), as claimed in the text. Then (7) gives

$$-\frac{u_h}{u_c} = \frac{1+\eta}{\eta} - \frac{g}{h} < 1. \tag{29}$$

This delivers (15), as claimed in the text. Based on these results, conditions (24), (25), and (28), respectively, simplify to

$$u_c - \gamma^1 \frac{u_{cc}h}{\theta}\left(1+\eta-\eta\frac{g}{h}\right) - \gamma^3 = 0 \tag{30}$$

$$u_h - \gamma^1 \frac{u_c}{\theta}\left(1+\eta+\eta\left(\frac{u_h}{u_c}+h\frac{u_{hh}}{u_c}\right)\right) + \gamma^3 = 0 \tag{31}$$

$$u_g + \gamma^1 \frac{u_c}{\theta}\eta - \gamma^3 = 0. \tag{32}$$

Eliminating γ^3 from (31) and (32) gives

$$\frac{u_h + u_g}{\frac{u_c}{\theta}\left(1+\eta\frac{u_h}{u_c}+\eta h\frac{u_{hh}}{u_c}\right)} = \gamma^1, \tag{33}$$

which shows $-u_h < u_g$, as claimed by (14) in the text, provided $\gamma^1 > 0$.

Now, in fact, we show $\gamma^1 \leq 0$ contradicts (29). Because then (33) implies $u_g \leq -u_h$, while (32) implies $\gamma^3 \leq u_g$. Thereby (30) gives

$$\begin{aligned} u_c &= \gamma^3 + \gamma^1 \frac{u_{cc}h}{\theta}\left(1+\eta-\eta\frac{g}{h}\right) \\ &< \gamma_3 \\ &\leq u_g \\ &\leq -u_h, \end{aligned}$$

where the first inequality uses $1+\eta-\eta g/h < 0$ from (29). Therefore $u_c \leq -u_h$, which contradicts (29) as claimed.

A.2 Fiscal-reaction function

The Lagrangian of the fiscal authority's problem (16) is

$$
\begin{aligned}
&\max_{\{c_{t+j}, h_{t+j}, \Pi_{t+j}, g_{t+j}\}} \sum_{j=0}^{\infty} \beta^j \Big\{ u(c_{t+j}, h_{t+j}, g_{t+j}) \\
&+ \gamma^1_{t+j} \left[u_{ct+j}(\Pi_{t+j} - 1)\Pi_{t+j} - \frac{u_{ct+j} h_{t+j}}{\theta} \left(1 + \eta + \eta \left(\frac{u_{ht+j}}{u_{ct+j}} - \frac{g_{t+j}}{h_{t+j}} \right) \right) \right. \\
&- \left. \beta u_{ct+j+1}(\Pi_{t+j+1} - 1)\Pi_{t+j+1} \right] \\
&+ \gamma^2_{t+j} \left[\frac{u_{ct+j}}{R_{t+j}} - \beta \frac{u_{ct+j+1}}{\Pi_{t+j+1}} \right] \\
&+ \gamma^3_{t+j} \left[h_{t+j} - c_{t+j} - \frac{\theta}{2} (\Pi_{t+j} - 1)^2 - g_{t+j} \right] \Big\},
\end{aligned}
$$

where $c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j-1}$, and g_{t+j} are taken as given for $j \geq 1$.

The first-order conditions with respect to c_t, h_t, Π_t, and g_t, respectively, are

$$
u_{ct} + \gamma^1_t \left(u_{cct}(\Pi_t - 1)\Pi_t - \frac{u_{cct} h_t}{\theta} \left(1 + \eta - \eta \frac{g_t}{h_t} \right) \right) + \gamma^2_t \frac{u_{cct}}{R_t} - \gamma^3_t = 0 \tag{34}
$$

$$
u_{ht} - \gamma^1_t \frac{u_{ct}}{\theta} \left(1 + \eta + \eta \left(\frac{u_{ht}}{u_{ct}} + h_t \frac{u_{hht}}{u_{ct}} \right) \right) + \gamma^3_t = 0 \tag{35}
$$

$$
\gamma^1_t u_{ct}(2\Pi_t - 1) - \gamma^3_t \theta (\Pi_t - 1) = 0 \tag{36}
$$

$$
u_{gt} + \gamma^1_t \frac{u_{ct}}{\theta} \eta - \gamma^3_t = 0. \tag{37}
$$

Conditions (36) and (37) imply

$$
\gamma^1_t = \frac{u_{gt} \theta (\Pi_t - 1)}{u_{ct}(2\Pi_t - 1 - \eta(\Pi_t - 1))}.
$$

Using this and (37) to eliminate γ^3_t in (35) delivers FRF, as claimed in the text.

A.3 Monetary-reaction function

The Lagrangian of the monetary authority's problem (18) is

$$\max_{\{c_{t+j},h_{t+j},\Pi_{t+j},R_{t+j}\}} \sum_{j=0}^{\infty} \beta^j \Big\{ u(c_{t+j}, h_{t+j}, g_{t+j})$$
$$+ \gamma^1_{t+j} \left[u_{ct+j}(\Pi_{t+j} - 1)\Pi_{t+j} - \frac{u_{ct+j}h_{t+j}}{\theta} \left(1 + \eta + \eta \left(\frac{u_{ht+j}}{u_{ct+j}} - \frac{g_{t+j}}{h_{t+j}} \right) \right) \right.$$
$$\left. - \ \beta u_{ct+j+1}(\Pi_{t+j+1} - 1)\Pi_{t+j+1} \right]$$
$$+ \gamma^2_{t+j} \left[\frac{u_{ct+j}}{R_{t+j}} - \beta \frac{u_{ct+j+1}}{\Pi_{t+j+1}} \right]$$
$$+ \gamma^3_{t+j} \left[h_{t+j} - c_{t+j} - \frac{\theta}{2}(\Pi_{t+j} - 1)^2 - g_{t+j} \right] \Big\},$$

where $c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j}$, and g_{t+j-1} are taken as given for $j \geq 1$.

The first-order conditions with respect to c_t, h_t, Π_t, and R_t, respectively, are

$$u_{ct} + \gamma^1_t \left(u_{cct}(\Pi_t - 1)\Pi_t - \frac{u_{cct}h_t}{\theta} \left(1 + \eta - \eta \frac{g_t}{h_t} \right) \right) + \gamma^2_t \frac{u_{cct}}{R_t} - \gamma^3_t = 0 \tag{38}$$

$$u_{ht} - \gamma^1_t \frac{u_{ct}}{\theta} \left(1 + \eta + \eta \left(\frac{u_{ht}}{u_{ct}} + h_t \frac{u_{hht}}{u_{ct}} \right) \right) + \gamma^3_t = 0 \tag{39}$$

$$\gamma^1_t u_{ct}(2\Pi_t - 1) - \gamma^3_t \theta(\Pi_t - 1) = 0 \tag{40}$$

$$-\gamma^2_t \frac{u_{ct}}{R^2_t} = 0. \tag{41}$$

Condition (41), $u_{ct} > 0$, and $R_t \geq 1$ imply

$$\gamma^2_t = 0.$$

Next, (38), (39), and (40), respectively, give

$$\gamma^3_t = u_{ct} + \gamma^1_t \left(u_{cct}(\Pi_t - 1)\Pi_t - \frac{u_{cct}h_t}{\theta} \left(1 + \eta - \eta \frac{g_t}{h_t} \right) \right) \tag{42}$$

$$\gamma^3_t = -u_{ht} + \gamma^1_t \frac{u_{ct}}{\theta} \left(1 + \eta + \eta \left(\frac{u_{ht}}{u_{ct}} + h_t \frac{u_{hht}}{u_{ct}} \right) \right) \tag{43}$$

$$\gamma^3_t = \gamma^1_t \frac{u_{ct}\,(2\Pi_t - 1)}{\theta\,(\Pi_t - 1)}. \tag{44}$$

Then (42) and (44) imply

$$\gamma_t^1 = \frac{\theta}{\frac{2\Pi_t - 1}{\Pi_t - 1} - \frac{u_{cct}}{u_{ct}}\left(\theta(\Pi_t - 1)\Pi_t - h_t\left(1 + \eta - \eta\frac{g_t}{h_t}\right)\right)}. \tag{45}$$

While (43) and (44) imply

$$\gamma_t^1 = \frac{\theta}{\frac{u_{ct}}{u_{ht}}\left[1 + \eta - \frac{2\Pi_t - 1}{\Pi_t - 1} + \eta\left(\frac{u_{ht}}{u_{ct}} + h_t\frac{u_{hht}}{u_{ct}}\right)\right]}. \tag{46}$$

Therefore equating (45) and (46) delivers MRF, as claimed in the text.

A.4 Proof of proposition 2

In a steady state in which $\Pi = 1$ the MRF simplifies to $-u_h = u_c$. At the same time, though, equation (7) implies $-u_h < u_c$ when $\Pi = 1$. The MRF then cannot hold at $\Pi = 1$. Moreover, equation (8) and $R \geq 1$ imply $\Pi \geq \beta$. Therefore it must be that $\Pi > 1$ if β is sufficiently close to 1, as claimed.

A.5 Utility weights

With household preferences (19), the Ramsey marginal condition (15) implies

$$\omega_h = \frac{1}{ch^{\varphi}}\left(\frac{1+\eta}{\eta} - \frac{g}{h}\right). \tag{47}$$

While first-order conditions (24), (25), and (28), respectively, imply

$$u_c - \gamma^1\left(\frac{u_{cc}h}{\theta}\left(1 + \eta - \eta\frac{g}{h}\right)\right) - \gamma^3 = 0 \tag{48}$$

$$u_h - \gamma^1\frac{u_c}{\theta}\left(1 + \eta + \eta\left(\frac{u_h}{u_c} + h_t\frac{u_{hh}}{u_c}\right)\right) + \gamma^3 = 0 \tag{49}$$

$$u_g + \gamma^1\frac{u_c}{\theta}\eta - \gamma^3 = 0. \tag{50}$$

Eliminating γ^3 from (48) and (49) gives

$$\gamma^1 = \frac{u_c + u_h}{\frac{u_{cc}h}{\theta}\left(1+\eta-\eta\frac{g}{h}\right) + \frac{u_c}{\theta}\left(1+\eta+\eta\left(\frac{u_h}{u_c}+h_t\frac{u_{hh}}{u_c}\right)\right)}.$$

Equation (48) also gives

$$\gamma^3 = u_c - \gamma^1\left(\frac{u_{cc}h}{\theta}\left(1+\eta-\eta\frac{g}{h}\right)\right).$$

Then (50) delivers

$$\omega_g = g\left(\gamma^3 - \gamma^1\frac{1}{c}\frac{\eta}{\theta}\right). \tag{51}$$

A.6 Welfare loss

Let $u(c,h,g)$ denote period utility in the Ramsey allocation, and let $u\left(c^A,h^A,g^A\right)$ denote period utility in an alternative policy regime. Then the permanent reduction in private consumption, $\mu^A \leq 0$, that would make welfare in the Ramsey allocation equivalent to welfare in the alternative policy regime, is given by

$$\begin{aligned}\frac{1}{1-\beta}u\left(c^A,h^A,g^A\right) &= \frac{1}{1-\beta}u\left(c(1+\mu^A),h,g\right)\\ &= \frac{1}{1-\beta}\left[u(c,h,g)+\log\left(1+\mu^A\right)\right],\end{aligned}$$

where the second equality uses (19). Therefore

$$\mu^A = \exp\left[u\left(c^A,h^A,g^A\right) - u(c,h,g)\right] - 1.$$

A.7 Conservative monetary-reaction function

The Lagrangian of the conservative monetary authority's problem (20) is

$$\max_{\{c_{t+j},h_{t+j},\Pi_{t+j},R_{t+j}\}} \sum_{j=0}^{\infty} \beta^j \Bigg\{ (1-\alpha)\, u(c_{t+j}, h_{t+j}, g_{t+j}) - \frac{\alpha}{2}\left(\Pi_{t+j}-1\right)^2$$

$$+ \gamma^1_{t+j} \Bigg[u_{ct+j}(\Pi_{t+j}-1)\Pi_{t+j} - \frac{u_{ct+j}h_{t+j}}{\theta}\left(1+\eta+\eta\left(\frac{u_{ht+j}}{u_{ct+j}} - \frac{g_{t+j}}{h_{t+j}}\right)\right)$$

$$- \ \beta u_{ct+j+1}(\Pi_{t+j+1}-1)\Pi_{t+j+1}\Bigg]$$

$$+ \gamma^2_{t+j}\left[\frac{u_{ct+j}}{R_{t+j}} - \beta\frac{u_{ct+j+1}}{\Pi_{t+j+1}}\right]$$

$$+ \gamma^3_{t+j}\left[h_{t+j} - c_{t+j} - \frac{\theta}{2}(\Pi_{t+j}-1)^2 - g_{t+j}\right]\Bigg\},$$

where $c_{t+j}, h_{t+j}, \Pi_{t+j}, R_{t+j}$, and g_{t+j-1} are taken as given for $j \geq 1$.

The first-order conditions with respect to c_t, h_t, Π_t, and R_t, respectively, are

$$(1-\alpha)\, u_{ct} + \gamma^1_t\left(u_{cct}(\Pi_t-1)\Pi_t - \frac{u_{cct}h_t}{\theta}\left(1+\eta-\eta\frac{g_t}{h_t}\right)\right) + \gamma^2_t\frac{u_{cct}}{R_t} - \gamma^3_t = 0 \tag{52}$$

$$(1-\alpha)\, u_{ht} - \gamma^1_t\frac{u_{ct}}{\theta}\left(1+\eta+\eta\frac{u_{ht}}{u_{ct}} + \eta h_t\frac{u_{hht}}{u_{ct}}\right) + \gamma^3_t = 0 \tag{53}$$

$$\gamma^1_t u_{ct}(2\Pi_t-1) - \gamma^3_t\theta(\Pi_t-1) - \alpha\left(\Pi_t-1\right) = 0 \tag{54}$$

$$-\gamma^2_t\frac{u_{ct}}{R_t^2} = 0. \tag{55}$$

Conditions (55), $u_{ct} > 0$, and $R_t \geq 1$ imply

$$\gamma^2_t = 0.$$

Next, (52), (53), and (54), respectively, give

$$\gamma^3_t = (1-\alpha)\, u_{ct} + \gamma^1_t\left(u_{cct}(\Pi_t-1)\Pi_t - \frac{u_{cct}h_t}{\theta}\left(1+\eta-\eta\frac{g_t}{h_t}\right)\right) \tag{56}$$

$$\gamma^3_t = -\left(1-\alpha\right) u_{ht} + \gamma^1_t\frac{u_{ct}}{\theta}\left(1+\eta+\eta\left(\frac{u_{ht}}{u_{ct}} + h_t\frac{u_{hht}}{u_{ct}}\right)\right) \tag{57}$$

$$\gamma^3_t = \gamma^1_t\frac{u_{ct}(2\Pi_t-1)}{\theta(\Pi_t-1)} - \frac{\alpha}{\theta}. \tag{58}$$

Then (56) and (58) imply

$$\gamma_t^1 = \frac{\theta\left(1-\alpha+\frac{1}{u_{ct}}\frac{\alpha}{\theta}\right)}{\frac{2\Pi_t-1}{\Pi_t-1}-\frac{u_{cct}}{u_{ct}}\left(\theta(\Pi_t-1)\Pi_t-h_t\left(1+\eta-\eta\frac{g_t}{h_t}\right)\right)}. \tag{59}$$

While (57) and (58) imply

$$\gamma_t^1 = \frac{\theta\left(1-\alpha-\frac{1}{u_{ht}}\frac{\alpha}{\theta}\right)}{\frac{u_{ct}}{u_{ht}}\left(1+\eta-\frac{2\Pi_t-1}{\Pi_t-1}+\eta\left(\frac{u_{ht}}{u_{ct}}+h_t\frac{u_{hht}}{u_{ct}}\right)\right)}. \tag{60}$$

Therefore equating (59) and (60) delivers CMRF, as claimed in the text.

Definition	Parameter	Value
Discount factor	β	0.9913 quarterly
Price elasticity of demand	η	-6
Degree of price stickiness	θ	17.5
Labor-supply elasticity	φ^{-1}	1
Labor-income tax rate	τ	24%
Utility weight on labor effort	ω_h	19.7917
Utility weight on public goods	ω_g	0.2656

Table 1: Baseline calibration

Policy regime	c	h	Π	g	τ	Welfare loss
	Difference from Ramsey (%)				Level (%)	Difference from Ramsey (%)
SP	-7.08	5.90	4.47	14.21	25.71	-8.26
OI	-13.73	-0.05	2.11	44.89	34.67	-4.76

Notes: Using the baseline calibration, the table shows the effects in steady state of sequential monetary and fiscal policy (SP), and of an optimal-inflation (OI) regime in which monetary policy is committed in advance. Shown are the effects on private consumption c, hours worked h, gross inflation Π, public goods g, the labor-income tax rate τ, and the welfare loss as measured by the permanent loss in private consumption.

Table 2: Effects of sequential policy

Calibration	$\Pi^{SP} - \Pi^{OI}$ (%)	Welfare loss Difference from Ramsey (%) SP	OI
Baseline	2.36	−8.26	−4.76
Stickier prices ($\theta = 50$)	2.04	−11.70	−5.92
Less sticky prices ($\theta = 5$)	2.13	−4.20	−2.94
Almost flexible prices ($\theta = 0.1$)	0.15	−0.13	−0.13
Less competition ($\eta = -5$)	2.61	−11.90	−7.56
More competition ($\eta = -9$)	1.31	−3.28	−1.92
Almost perfect competition ($\eta = -30$)	0.06	−0.16	−0.15
High labor-supply elasticity ($\varphi = 0.1$)	3.27	−11.60	−6.89
Low labor-supply elasticity ($\varphi = 3$)	0.73	−3.14	−2.39
Almost inelastic labor supply ($\varphi = 8$)	0.07	−0.66	−0.62

Notes: See notes to table 2. The middle column shows the difference between gross inflation in the SP regime and in the OI regime. A positive value of such difference indicates inflation conservatism is desirable.

Table 3: Robustness of the effects of sequential policy

Calibration	α^{opt}		Welfare loss	
			Difference from Ramsey (%)	
	Nash	ML	Nash and ML	
			$\alpha = \alpha^{opt}$	$\alpha = 1$
Baseline	0.995	0.997	−4.76	−7.96
Stickier prices ($\theta = 50$)	0.999	0.999	−5.92	−7.96
Less sticky prices ($\theta = 5$)	0.963	0.982	−2.94	−7.96
Almost flexible prices ($\theta = 0.1$)	0.015	0.300	−0.13	−7.96
Less competition ($\eta = -5$)	0.995	0.996	−7.56	−13.71
More competition ($\eta = -9$)	0.993	0.996	−1.92	−3.76
Almost perfect competition ($\eta = -30$)	0.939	0.991	−0.15	−1.40
High labor-supply elasticity ($\varphi = 0.1$)	0.996	0.996	−6.89	−10.94
Low labor-supply elasticity ($\varphi = 3$)	0.987	0.996	−2.39	−6.52
Almost inelastic labor supply ($\varphi = 8$)	0.925	0.993	−0.62	−5.83

Notes: See notes to table 2. The middle column shows the optimal degree of inflation conservatism that in the Nash and monetary leadership (ML) regimes recovers the level of welfare of the OI regime.

Table 4: Robustness of the welfare gain from inflation conservatism

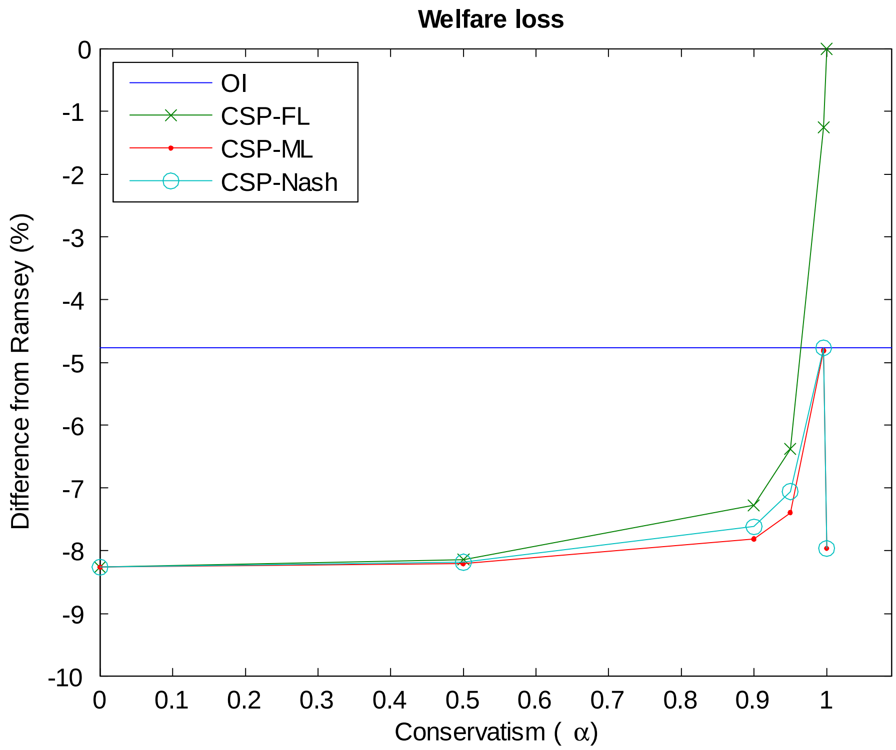

Figure 1: Welfare gain from inflation conservatism under the baseline calibration

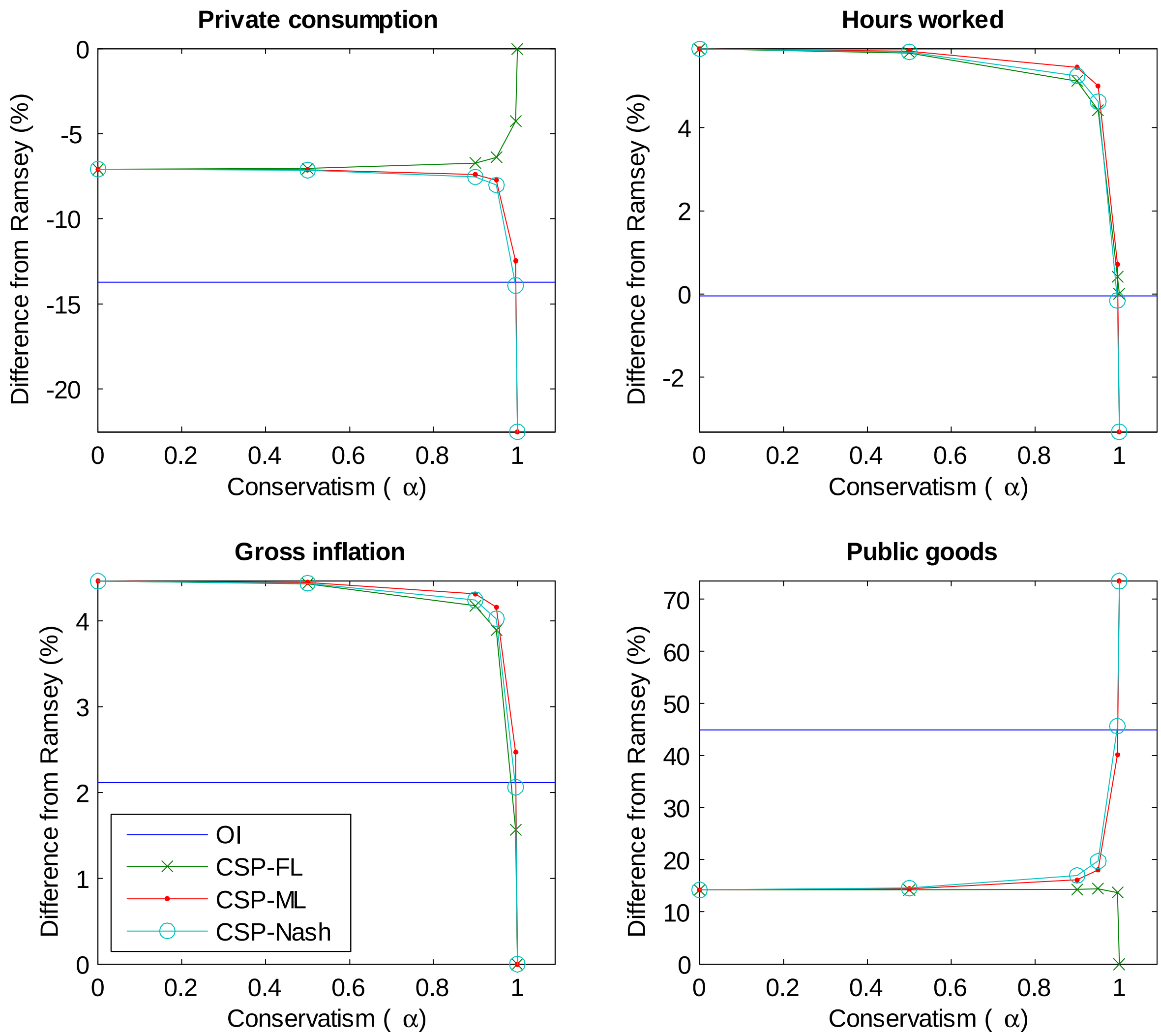

Figure 2: Effects of inflation conservatism under the baseline calibration