Interactions of Commitment and Discretion in Monetary and Fiscal Policies

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Abstract

We consider monetary-fiscal interactions when the monetary authority is more conservative than the fiscal (lower ideal output and price level, and less weight on output). With both policies discretionary, (1) Nash equilibrium yields lower output and higher price than the ideal points of both authorities, (2) of the two leadership possibilities, fiscal leadership is generally better. With fiscal discretion, monetary commitment yields the same outcome as discretionary monetary leadership for all realizations of shocks. But fiscal commitment is not similarly negated by monetary discretion. Second-best outcomes require either joint commitment, or identical targets for the two authorities - output socially optimal and price level appropriately conservative.

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1 Introduction

Many countries have made their central banks increasingly independent of day-to-day political control. Canada, Italy and New Zealand increased the degree of independence of their central banks in the 1990s; Australia, Canada, New Zealand, Sweden and United Kingdom instituted explicit inflation targets for theirs; the Maastricht Treaty assigns price stability (defined as a 2% annual change) as the primary goal for the European Central Bank. The central banks are often more conservative than the politicians who run the treasury, either by explicit mandate or by natural inclination.

This shift toward central bank independence and conservatism is the result of the experience of high inflation in the 1970s in the United States and Europe and even the early 1980s in many Latin American countries, and the intellectual stimulus given by the work of Barro and Gordon (1983), Rogoff (1985 a) and Svensson (1997). These works, which model monetary policy alone, suggest that governments should delegate monetary policy to a central bank that is instrument independent and appropriately conservative. A central bank is instrument independent if it has full control over the instruments of monetary policy and therefore over the decision of how much of the fiscal deficit to monetize. By appropriately conservative, this literature means that the central bank's output and/or inflation targets should be lower than the socially optimal ones *and* that the central bank should put more weight on inflation stabilization and less on output stabilization than society does. Central bank independence and conservatism eliminates the inflation bias of monetary policy that results from the incentive to exploit surprise inflation to raise output in the short run above its natural level, which is typically assumed to be inefficiently low.

We take this independence and conservatism as our starting point, and examine its consequences. Specifically, we consider the interaction between such a central bank, and the fiscal authority. When monetary and fiscal policies are made by these separate authorities with different objectives, macroeconomic policymaking becomes a noncooperative game between them. Depending on the structure of the game, this may yield a Nash or a leadership equilibrium, either with commitment to a policy rule or discretionary actions after economic shocks are realized. These noncooperative equilibria can be suboptimal.

In this paper, we consider such interaction. We model an economy with monopolistic competition and nominal rigidities.[1] Monopoly power over the produced good makes output inefficiently low and gives policymakers an incentive to use their policies to raise production in equilibrium. Fiscal policy, in the form of a production subsidy, increases the supply of goods and can achieve the efficient level of output. If fiscal policy creates deadweight losses, it would not be socially optimal to subsidize production to its efficient level. This leaves an output gap that policymakers wish to close with unanticipated policies. An unanticipated monetary expansion raises output and the price level because of staggered prices; an unanticipated supply-side fiscal policy, such as a production subsidy, increases the supply of goods and it may also lower private demand and prices if financed by per-head taxation. These economic effects interact through the strategic choices of the two authorities.

[1]We follow Woodford (1999) and the related literature currently used to study optimal monetary policy.

Our main findings are worth emphasis at the outset:

1. If neither type of policy has commitment or leadership, the interaction between a conservative central bank in the sense of Rogoff (1985 a) and Svensson (1997) and a fiscal authority that maximizes social welfare leads to suboptimal and extreme outcomes. More precisely, the Nash equilibrium is *not* second-best; output is lower and the price level higher than what either authority wants. Time inconsistency makes fiscal policy too tight and monetary policy too loose, resulting in output being lower and prices being higher than optimal.

2. Giving leadership (first-mover advantage) to fiscal policy produces outcomes preferable to the Nash equilibrium and, generally, to monetary leadership. Fiscal leadership, however, is not second best.

3. The time-consistency problem of monetary policy can be solved by commitment to a rule specifying how the actual policy choice will respond to all possible realizations of the stochastic shocks. But with discretionary fiscal policy chosen by a strategic fiscal authority, the ex post reaction function of the fiscal authority acts as a constraint on the monetary rule. We find that this entirely negates the advantage of monetary commitment – the optimal monetary rule is no different than discretionary leadership of monetary over fiscal policy for every realization of the shocks. Thus fiscal discretion eliminates the gains of monetary commitment. Fiscal commitment, on the other hand, removes the excessive tightness of fiscal policy stemming from the desire to reduce deadweight losses and surprise expectations. Even though the ex post reaction function of the monetary authority constraints the fiscal rule, monetary discretion does not completely eliminates the gains of fiscal commitment.

4. Commitment achieves the second best only if it can be extended to both monetary and fiscal policy. Alternatively, commitment of fiscal policy with a conservative central bank in the sense of Rogoff (1985 a) and Svensson (1997) achieves the second best.

5. If commitment to a policy rule is not an option, the second best can be achieved by appropriately assigning goals to policies. Two alternative assignments are possible. First, the two authorities should have identical targets, the output target being the social optimum and the price target being conservative. Second, the monetary authority should care only about the price target while the fiscal authority should care only about the output target.

2 Literature Review

The large literature on commitment and discretion in monetary policy, initiated by Kydland and Prescott (1977) and Barro and Gordon (1983), assumes that distortions create short-run benefits from unexpected inflation and studies the equilibria that arise under different institutional arrangements and their welfare properties. Typically, the first-best equilibrium can be achieved by eliminating the distortions; the second-best equilibrium can be achieved by commitment to a monetary policy rule; discretionary monetary policy leads to a fourth-best equilibrium. Improvements over discretion that lead to third- or even second-best equilibria can be obtained by delegation of monetary policy to a conservative central banker, as suggested by Rogoff (1985 a), or simple inflation targets, as suggested by Svensson (1997). An optimal central bank contract along the lines of Walsh (1995) and Persson and Tabellini (1993) can achieve the second best. All these works do not consider fiscal policy or simply assume it as exogenous. We study the equilibria of the game where the fiscal authority is a strategic player and show that commitment to a monetary policy rule fails to lead to the second-best allocation.

The literature on commitment and discretion in monetary policy considers additive stochastic shocks and studies linear monetary policy rules; one exception is Persson and Tabellini (1993), which allows for a general stochastic structure and characterizes, but does not solve explicitly for the optimal monetary policy rule. We allow very general stochastic shocks to the parameters, and find the fully optimal monetary policy rule as a nonlinear function of these shocks.

Our paper is related to three analyses of the interaction of monetary and fiscal policies. [1] Alesina and Tabellini (1987) consider a one-country model where the monetary authority chooses the inflation rate and the fiscal authority chooses the tax rate to finance government expenditures; both authorities have identical, explicit goals for inflation, output and the level of government expenditures but different tradeoffs among the goals. They find that monetary commitment might not be welfare improving when the two authorities assign different weights to their goals because the reduction in seignorage induces higher taxes (in order to achieve the public spending target) and lower output, which can more than compensate the gain stemming from lower inflation. Our paper differs from Alesina and Tabellini (1987) in several respects. First, we concentrate on the stabilization of the price level and output, and therefore abstract from government-spending targets. Second, and most importantly, when they briefly consider the case with no government spending target, their model does not have a time-consistency problem, so that output and inflation are at their targeted levels. Third, the two authorities have identical targets but possibly different weights for them in Alesina and Tabellini; we allow for the more general case where not only weights but also objectives are more conservative for the central bank. [2] Debelle and Fischer (1994) consider the case where the monetary authority has no explicit preferences about the level of public expenditures and consider Nash and Stackelberg equilibria, but do not consider state-contingent monetary rules. [3] Banerjee (1997) uses a model similar to ours in many respects. But first he considers only the pure time-consistency problem in a non-stochastic environment, and when later he introduces two additive stochastic shocks, allows only policy commitments to fixed numbers rather than any state-contingent rules, linear or otherwise.

Dixit and Lambertini (2000 a, 2001) consider two related models for the case of a monetary union. In these models, there is no time-consistency problem of monetary policy; the first work considers a special case where the ideal points of all countries' fiscal authorities and the common central bank coincide; then the ideal outcomes can be achieved despite any disagreements about tradeoffs between the objectives and for any order of moves. The second paper considers the case of conflicting objectives between the fiscal authorities and the common central bank in a monetary union when the preferences of the fiscal authorities are exogenously given; it finds that the interaction of monetary and fiscal policies leads to extreme output and inflation outcomes. The contribution of this paper above Dixit and Lambertini (2001) is that it considers explicitly the case of time-inconsistent monetary and fiscal policies and carries out a welfare analysis of the interaction of monetary and fiscal policy when the authorities have conflicting objectives.

Our work shows that if both monetary and fiscal policies have a time-consistency problem, making the monetary, but not the fiscal, authority conservative may make things worse. The general idea behind our result – a reminiscent of the second best theory – is present in other works on policymaking with multiple strategic interactions. Rogoff (1985 b) and Kehoe (1989), for example, show that cooperation between two governments with an incentive toward time-inconsistent behavior may reduce welfare as lack of policy cooperation acts as a disciplining device.

3 The Model

The structural model underlying our analysis has monopolistic competition and staggered prices. Output is suboptimally low because of the monopolistic power of firms. Fiscal policy consists of a production subsidy financed by per-head taxes, which counters the monopoly distortion, and therefore fits most naturally with the structure of the model; fiscal policy, however, generates deadweight losses. Unanticipated monetary policy changes have real effects because of staggered price-setting. Log-linearization around the steady state yields our working model consisting of equations (1) and (2) below; it is like the Barro-Gordon (1983) model extended to include fiscal as well as monetary policy. The details of the structure are in appendix A.[2]

There are two policymakers in the country: the central bank and the fiscal authority. The central bank chooses a policy variable m, which stands for some actual policy variable such as the base money supply or a nominal interest rate, and determines a component of the price level; thus higher m means a more expansionary monetary policy. The fiscal authority chooses a policy variable x; a larger x means a larger subsidy and a more expansionary fiscal policy.

These policies affect the GDP level y and the price level π in the country. Let π^e denote the private sector's rational expectation of π. We assume that the real GDP y of the country is given by

$$y = \overline{y} + a\, x + b\, (\pi - \pi^e), \tag{1}$$

[2] Available at http://econweb.sscnet.ucla.edu/lambertini/papers/fiscdiscapp.pdf

and the price level π is given by

$$\pi = m + c\,x\,. \tag{2}$$

The explanation of the parameters in the output equation (1) is as follows: [1] $\overline{y}$ is the natural rate of output without any fiscal policy; this is suboptimally low because of monopolistic competition. [2] The scalar a is the direct effect of fiscal policy on GDP. A production subsidy counters the monopoly distortion and has an expansionary effect on GDP; hence $a > 0$. [3] The last term on the right-hand side of equation (1) is the usual supply effect of an unexpected increase in the price level; thus $b > 0$.

Turning to equation (2), the price level is a sum of the component m which is the controlled part of monetary policy or its initial stance, and a further contribution arising from fiscal policy. A production subsidy that raises the supply of goods and services reduces prices; hence, $c < 0$. The overall effect of fiscal policy on output, $a + bc$, is positive as long as the deadweight losses from fiscal policy are not too large.[3]

Equations (1) and (2) show that both monetary and fiscal policies have a time-consistency problem. With staggered prices, monetary policy is too expansionary, as the central bank tries to raise private demand and therefore output; on the other hand, fiscal policy is not expansionary enough, as the fiscal authority tries to boost production in the firms with pre-set prices.

The social loss function representing the losses of the representative agent is given by

$$L_F = \frac{1}{2}\left[(\pi - \pi_F)^2 + \theta_F (y - y_F)^2 + 2\delta x\right]. \tag{3}$$

This social loss function is derived in appendix B[4] on the basis of our microfounded model. π_F is the average level of the pre-set prices in the economy and it is socially optimal to minimize price level dispersion. The GDP that minimizes social losses is such that $y_F \geq \overline{y}$ and extra output is desirable. Fiscal policy can raise output above its natural rate, but it creates deadweight losses $\delta > 0$ in doing so. $\theta_F > 0$ parameterizes the social preference for the output versus the price-level goals.

Fiscal policy is chosen by a fiscal authority that minimizes the social loss function (3). Monetary policy is chosen by a monetary authority that is conservative in a way that encompasses both Rogoff's and Svensson's definition, and minimizes a loss function

$$L_M = \frac{1}{2}\left[\theta_M (y - y_M)^2 + (\pi - \pi_M)^2\right]. \tag{4}$$

Interpretations of the parameters y_M, π_M and θ_M are analogous to the corresponding parameters for the social loss function. The central bank is more conservative than society in the sense that $\theta_M \leq \theta_F$ and/or $\pi_M \leq \pi_F, y_M \leq y_F$.

[3] The model in Appendix A considers one specific kind of fiscal policy. But equations (1) and (2) can be interpreted as the reduced form arising from other types of fiscal policies, such as government spending to purchase goods or a supply-side fiscal policy financed by distortionary income taxes. The algebra is unchanged but the interpretations of the parameters a, b and c and their signs and values can differ. The working paper version, Dixit and Lambertini (2000 b), discusses such cases.

[4] Available at http://econweb.sscnet.ucla.edu/lambertini/papers/fiscdiscapp.pdf

The natural rate of output $\overline{y}$, the scalar parameter a summarizing the fiscal policy effect on GDP, the scalar parameter b for the supply effect of unexpected price changes, the scalar parameter c of the effect of fiscal policy on the price level, the scalar parameter δ for the deadweight loss of fiscal policy and the scalar parameter θ_F for the social preferences, are all stochastic shocks. We denote the whole vector of these shocks by $z = (\overline{y}, a, b, c, \delta, \theta_F)$. The policy variables m and x are implemented after the shocks are observed, and therefore are written as functions $m(z)$ and $x(z)$ (although the functional form may be fixed before the shocks are observed in regimes where policies are precommitted). The resulting outcomes of GDP and price are then also realization-specific or functions $y(z)$ and $\pi(z)$.

The literature in this area usually considers only linear policy rules – it restricts the form of the function $m(z)$ to be linear, and then finds the optimal values of the coefficients in this function. Since linear rules are not in general optimal, it becomes necessary to restrict the stochastic shocks; only additive shocks like our $\overline{y}$ are considered. Our stochastic structure is richer and we allow $m(z)$ to be arbitrary, and find the fully optimal rule.

The private sector's expectations are formed before any of these shocks are realized and before the policy variables are chosen; they do not depend on z. Thus equations (1) and (2) may be written with the z arguments as

$$y(z) = \overline{y} + a\, x(z) + b\, (\pi(z) - \pi^e), \tag{1'}$$

and

$$\pi(z) = m(z) + c\, x(z)\,. \tag{2'}$$

To simplify the notation, we drop the dependence of output, price level and the policy variables on z whenever it does not create confusion.

The condition of rational expectations is

$$\pi^e = E_z[\pi(z)] \equiv \int \pi(z), \tag{5}$$

where the integral is six-dimensional, taken with respect to the joint distribution of z.

We will consider various possible policy regimes. In absence of commitment, the two policies may be simultaneous (Nash) or one of them may be first (leadership). If monetary policy is precommitted, then it has leadership with respect to setting the rule, and fiscal policy is the follower in each state of the world (realization of the shocks); if fiscal policy is precommitted, it has leadership with respect to setting the rule, and monetary policy is the follower in each state of the world. There is no conclusive evidence about the correct choice from among the possibilities. It may be argued on the one hand that the central bank's reputational considerations give it an advantage in making and keeping commitments, and on the other hand that the lags in fiscal policy enable commitment there. Similar conflicting arguments can be made for the order of moves under discretion. Therefore we consider all possibilities.

Hence, the timing of events is as follows:

1. We consider three possible scenarios of commitment:

   (a) If there is joint commitment of the two policies, this is done in a coordinated manner using the fiscal authority's objective function, which coincides with social welfare.

   (b) If the fiscal policy regime is one of commitment, the fiscal authority chooses its policy rule $x = x(z)$; this specifies how it will respond to the stochastic shocks. If the fiscal regime is one of discretion, nothing happens at this step.

   (c) If the monetary policy regime is one of commitment, the central bank chooses its policy rule $m = m(z)$. If the monetary regime is one of discretion, nothing happens at this step.

2. The private sector forms expectations π^e.

3. The stochastic shocks $\overline{y}, a, b, c, \delta, \theta_F$ are realized.

4. (a) If the monetary policy regime is one of discretion, the central bank chooses m. If the monetary regime is one of commitment, the central bank simply implements the monetary rule m that was chosen at step 1.

   (b) If the fiscal regime is one of discretion, the fiscal authority chooses fiscal policy x. If the fiscal regime is one of commitment, the fiscal authority simply implements the fiscal rule x that was chosen at step 1.

   When monetary and fiscal policies are discretionary, the relative timing of step 4 (a) and 4 (b) raises some questions. In fact, monetary and fiscal policy may be chosen simultaneously or their order may be reversed.

We proceed to consider the different cases of commitment and sequence of moves.

4 Full Commitment

First we study the equilibrium with commitment of monetary and fiscal policy. Since both policies are time-inconsistent in this setting, full commitment delivers the socially optimal and feasible allocation; hence, it is the natural benchmark against which to compare all other equilibria.

Let both the monetary and fiscal authorities minimize the social loss function (3) and recognize the rational expectations constraint. At step 1 and 2, the two authorities choose the whole functions $m(\cdot), x(\cdot)$ to minimize the expected loss function

$$\int L_F(z) = \frac{1}{2} \int \left[(\pi(z) - \pi_F)^2 + \theta_F(y(z) - y_F)^2 + 2\delta x(z) \right] . \tag{6}$$

The substitution of π^e into the objective complicates the algebra, because it then involves one integration inside another. We avoid this by regarding the authorities as if they had another choice variable, namely π^e, but their choice was subject to the constraint (5). The common Lagrangean for this problem is as follows:

$$\mathcal{L}_{\mathcal{F}}^{\mathcal{FC}} = \int \left\{ \frac{1}{2} \left[\theta_F (y(z) - y_F)^2 + (\pi(z) - \pi_F)^2 + 2\delta x(z) \right] + \lambda \pi(z) \right\} - \lambda \pi^e, \tag{7}$$

where λ is the Lagrangean multiplier. The first-order condition with respect to the function $x(z)$ is given by

$$(\pi(z) - \pi_F + \lambda)c + \theta_F(a + bc)(y(z) - y_F) + \delta = 0. \tag{8}$$

The first-order condition with respect to the function $m(z)$ is given by

$$(\pi(z) - \pi_F + \lambda) + \theta_F b(y(z) - y_F) = 0. \tag{9}$$

The first-order condition with respect to π^e is given by

$$-\lambda - \int (\pi(z) - \pi_F + \lambda) = 0. \tag{10}$$

The fully optimal, nonlinear rules for monetary and fiscal policy imply

$$\pi(z) = \pi_F + \frac{\delta b}{a} - \int \frac{\delta b}{a}, \quad \pi^e = \pi_F, \quad y(z) = \tilde{y} = y_F - \frac{\delta}{a\,\theta_F}, \quad \lambda = \int \frac{\delta b}{a}. \tag{11}$$

If $\delta = 0$, full commitment delivers the first best allocation

$$y = y_F, \quad \pi = \pi_F.$$

If there are no deadweight losses from fiscal policy, i.e. $\delta = 0$, the optimal subsidy eliminates the inefficiency stemming from monopolistic competition. Output is at the first-best level and the time-consistency problem of monetary and fiscal policy disappears.

With deadweight losses from fiscal policy, i.e. $\delta > 0$, full commitment yields the socially optimal and feasible allocation that we refer to as second best. At the second best, there is no upward bias in the price level, which is on average π_F; output is below its efficient level because expansionary fiscal policy generates losses; the output gap, $\delta/(a\theta_F)$, is higher the larger the deadweight losses δ, the less important is output in social preferences θ_F, and the smaller the direct impact of fiscal policy on output a.

The rational expectations constraint is binding when all the m, x are chosen ex-ante optimally. More precisely, λ is the average reduction in the price level achieved by full commitment.[5] Intuitively, fiscal policy is more expansionary and monetary policy more contractionary under commitment, as the policy authorities know that any attempt to create a surprise increase in the price level is correctly anticipated by the private sector.

[5]In fact, $\delta b/a$ is the upward bias in the price level that would arise with discretionary monetary and fiscal policies. This result is shown in section 5.

5 Discretionary Policies and Nash equilibrium

In this policy regime, after each realization of the stochastic shock vector z, the fiscal authority chooses x, taking m as given, so as to minimize the loss function L_F; the monetary authority chooses m, taking x as given, so as to minimize its loss function L_M. The two authorities act non-cooperatively and simultaneously; however, when their choices are made, the private sector's expectations π^e are fixed. After completing the analysis of the policy equilibrium and economic outcome for an arbitrarily given state z, we can find π^e from the rational expectations condition (5).

The first-order condition for fiscal policy is obtained by differentiating (3) with respect to x, recognizing the dependence of π on x; this gives

$$\theta_F(y - y_F)(a + b\,c) + c(\pi - \pi_F) + \delta = 0,$$

or

$$\pi = \pi_F - \theta_F(\frac{a}{c} + b)(y - y_F) - \frac{\delta}{c}. \tag{12}$$

This defines the reaction function of the fiscal authority (FRF) in the (y, π) space. If required, one can obtain the reaction function in terms of the policy variables (m, x) by substituting y and π into (12) using (1) and (2). Since $c < 0$ and $a + bc > 0$, the FRF is positively sloped in the (y, π) space; its exact position depends on the realizations of the stochastic shocks a, b, c, δ and θ_F.

The first-order condition for monetary policy is obtained by differentiating (4) with respect to m, which gives

$$\theta_M(y - y_M)b + (\pi - \pi_M) = 0$$

or

$$\pi = \pi_M - \theta_M b\,(y - y_M). \tag{13}$$

This defines the reaction function for the monetary authority (MRF) in the (y, π) space. Since $b > 0$, the MRF is always negatively sloped.

The Nash equilibrium outcomes y and π are found by solving (12), (13) and (5) together and the solution is given in appendix C. Rational expectations imply $\pi^e = E[\pi]$ over the distribution of z, which is the expected value of the solution for π. Making use of (1) and (2) and $\pi^e = E[\pi]$, one can back out the policy variables x and m that emerge in equilibrium and deliver the Nash equilibrium outcomes for output and the price level. This is also done in appendix C.

Figure 1 depicts the MRF (13) and the FRF (12) in the (y, π) space. The MRF is the solid line thru point M, the bliss point for the conservative monetary authority; FRF is the solid line above point F, the bliss point for society and for the fiscal authority. F is the first-best allocation that cannot be achieved in the presence of deadweight losses from fiscal policy: with $\delta > 0$, FRF does not pass through point F because it is suboptimal to expand fiscal policy to reach the socially optimal level of output. The second best allocation is point C in Figure 1, where $y = \tilde{y} < y_F$ and $\pi = \pi_F$. The Nash equilibrium occurs at the

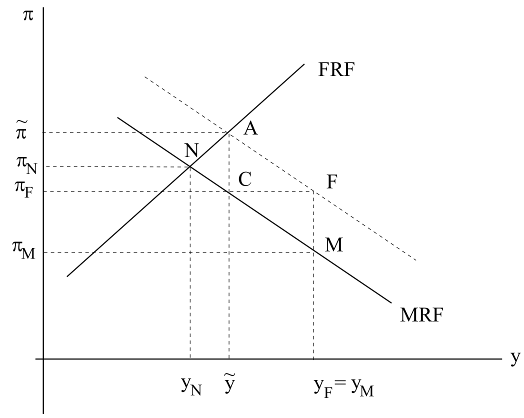

Figure 1: Nash Equilibrium

intersection of the two reaction functions MRF and FRF, and it is labelled N. We denote output and price at the Nash equilibrium by (y_N, π_N).[6]

We identify the following general characteristics of the Nash equilibrium:

$$y_N \leq y_M < y_F, \quad y_N \leq \tilde{y}, \quad \pi_N \geq \pi_F > \pi_M.$$

Only in the extreme special case where social welfare does not depend on the price level ($\theta_F \to \infty$) will the Nash equilibrium be second-best ($y_N = \tilde{y}$ and $\pi_N = \pi_F$). In the more general and realistic cases, both outcomes are more extreme than the ideal points of either policymaker: in the Nash equilibrium, output is lower and the price level higher than either policymaker want. Moreover, output is lower and the price level is higher in the Nash equilibrium, point N, than at the second-best allocation, point C.

The Nash equilibrium with a conservative central bank is extreme and suboptimal because of the time inconsistency of monetary and fiscal policies. Discretionary fiscal policy is less expansionary than committed fiscal policy. Once expectations are set, the government has an incentive to raise the price level so as to raise output. Since $c < 0$, this is achieved by tightening fiscal policy. Monetary policy also suffers from time inconsistency: once expectations are set, monetary policy will be expanded so as to raise output. In a rational expectation equilibrium, these incentives are perfectly anticipated and there is no systematic output gain from surprises in the price level. Since fiscal policy is less expansionary and monetary policy more expansionary, output is lower and the price level higher in the Nash equilibrium than under full commitment. The Nash outcome with too little output and too high inflation may have arisen in 1999-2000 in the newly formed Economic and Monetary Union of Europe (EMU).

If the central bank is not conservative and minimizes the loss function (3), then the MRF is the dotted line thru the first best, point F in Figure 1. In this case, the Nash equilibrium

[6] In drawing Figure 1, we have assumed that $\theta_M = \theta_F, y_M = y_F$ and $\pi_M = \pi_F - \frac{\delta b}{a}$, so that the MRF goes thru the second-best allocation, point C; the qualitative results, however, do not depend on these assumptions.

has the following properties:

$$y_N = \tilde{y} = y_F - \frac{\delta}{a\,\theta_F}, \qquad \pi_N = \tilde{\pi} = \pi_F + \frac{\delta b}{a}. \tag{14}$$

This is point A of Figure 1, which lies vertically above the second best, point C, because socially optimal monetary and fiscal policies are time-inconsistent. The upward bias in the price level is higher the stronger the incentive to contract fiscal policy (higher δ and lower a) and to surprise expectations (higher b).

Dixit and Lambertini (2000 a) consider the interaction between monetary policy of a common central bank and the separate fiscal policies of the member countries in a setting where monetary and fiscal policies do not have a time-consistency problem and the monetary authority has the same output and price goals as society, namely $y_F = y_M$ and $\pi_F = \pi_M$. It is shown that the socially optimal allocation is achieved without the need for commitment or fiscal coordination and irrespectively of which authority moves first. This intuition would carry through here: if there are no deadweight losses from fiscal policy, $\delta = 0$, and both authorities' bliss points coincide with F, then FRF and MRF go thru F and the Nash equilibrium coincides with the first-best allocation F.

5.1 Discretionary Monetary Policy with Non-Strategic Fiscal Policy

Barro and Gordon (1983), Rogoff (1985 a) and Svensson (1997) assume that fiscal policy is either absent or chosen non-strategically before the monetary authority acts. We briefly restate these results using the notation and techniques of our approach, to illustrate how our analysis stands apart from that literature. Suppose the fiscal authority is non-strategic and it either chooses the rule $\bar{x}(z)$ at stage 1, or the policy $\bar{x}$ at step 4 (b), *without* taking into account the central bank's behavior. We can redefine the natural rate of output including fiscal policy as

$$\hat{y} = \bar{y} + a\bar{x}. \tag{15}$$

The fiscal policy $\bar{x}$ can be the rule arising from full commitment and such that $\hat{y} = \tilde{y}$ or just any other policy, for example $\bar{x} = 0$ for all realization of the vector of shocks z; the results below do not rely on any specific assumption. In terms of Figure 1, non-strategic fiscal policy makes the FRF a vertical line at $y = \hat{y}$.

Let the monetary authority minimize the social loss function (3) subject to $x = \bar{x}$; the first-order condition for monetary policy gives

$$\pi = \pi_F - \theta_F b(y - y_F). \tag{16}$$

This is the dotted line thru point F in Figure 1. The average price level in this economy is

$$\int \pi = \pi_F - \int \theta_F b\left[\hat{y} + b(\pi - \pi^e) - y_F\right], \tag{17}$$

which is higher than π_F as long as $\hat{y} < y_F$. In words, if the natural rate of output including fiscal policy is below efficiency, discretionary monetary policy generates higher-than-optimal prices because the central bank attempts to close the output gap via a surprise monetary expansion.

To eliminate the upward bias in prices, the monetary authority should commit to a rule, if feasible; we discussed this alternative in Section 4. Alternatively, Rogoff (1985 a) suggests to delegate discretionary monetary policymaking to a central bank with greater concern for the price level than society, while Svensson (1997) suggests delegation to a central bank with more conservative price target than society. The loss function (4) encompasses both Rogoff's and Svensson's definition of conservatism. For given $y_M, \theta_M, \bar{x}$, it is socially optimal to set the central bank's price target at

$$\pi_M = \pi_F + \theta_M \int b(\hat{y} - y_M), \tag{18}$$

so that the price level is on average equal to π_F and output equal to $\hat{y}$.

If fiscal policy is strategic, an appropriately conservative central bank (as in Rogoff and Svensson) has price target

$$\pi_M = \pi_F + \theta_M \int b(\tilde{y} - y_M), \tag{19}$$

for given y_M, θ_M. This target ensures that the MRF goes thru point C in Figure 1 and is consistent with the second-best allocation.[7]

6 Discretionary Policies and Leadership Equilibria

Here we consider the case where both policies are discretionary, that is, chosen at step 4 without any commitment to a rule at step 1, but one of the policies is announced and fixed before the other, so one policymaker is the leader and the other the follower in the two-move subgame of step 4. It is not clear whether the timing of actions 4 (a) and 4 (b) should be as described or the other way round. The current policy debate seems to assume that the central bank moves first and the fiscal authority follows; hence, the central bank may fear that subsequent fiscal expansions will bring the price level well above its goal. The literature on monetary unions, for example Beetsma and Bovemberg (1998), has argued that it takes a long time to change tax rates whereas monetary policy can be adjusted quite quickly; hence the timing of 4 (a) and (b) should be actually reversed. We consider both possibilities.

6.1 Discretionary Policies and Monetary Leadership

Here we consider the case of monetary leadership. Monetary policy is open to discretionary choice at step 4 (a); when fiscal policy is chosen at step 4 (b), m is known. Private sector's expectations π^e are set before and known when m and x are chosen.

[7] If $y_F \geq y_M \geq \tilde{y}$, then $\pi_M \leq \pi_F$ in (19) and the central bank is more price-conservative than the fiscal authority.

Fiscal policy is exactly as described in section 5. The fiscal authority minimizes (3) with respect to x taking m and π^e as given. Hence, the fiscal authority's reaction function is still described by (12).

The monetary authority minimizes the loss function (4) with respect to m. We can use (12) and the defining equations (1), (2) to solve for the fiscal response x in terms of m, and substitute back into (1) and (2) to find y and π as functions of m incorporating the fiscal reaction. But it is much easier equivalently to regard the monetary authority as choosing y and π directly, subject to the fiscal authority's reaction function (12) as a constraint. The first-order conditions for this Lagrangean problem are

$$\begin{aligned} \theta_M\,(y - y_M) &= \lambda_{ML}\,\theta_F\,(a + bc) \\ \pi - \pi_M &= \lambda_{ML}\;c \end{aligned}$$

where λ_{ML} is the Lagrange multiplier. Combining these two, we have

$$\theta_M\,(y - y_M) - \theta_F\,(b + a/c)\,(\pi - \pi_M) = 0$$

or

$$\pi = \pi_M + \frac{\theta_M}{\theta_F\,(\,b + a/c)}\;(y - y_M). \tag{20}$$

The outcome in this case is then found by solving the monetary first-order condition (20) and the fiscal reaction equation (12) jointly. This gives the solution for y and π, whose derivation is spelled out in appendix D.

All of this happens separately for each realization of the vector z of stochastic shocks; thus all the magnitudes including the Lagrange multiplier λ_M are functions of z. Finally, we can find π^e by taking expectations using (5).

In terms of Figure 1, the first-order condition (20) defines a downward sloping line passing through point M that can be steeper or flatter than MRF depending on the realization of the stochastic parameters. Hence, in the monetary leadership equilibrium both output and prices can be either higher or lower than in the Nash equilibrium.

The monetary authority is always better off leading; on the other hand, the fiscal authority may or may not be better off with monetary leadership than Nash. Our numerical simulations show that social losses are typically lower under monetary leadership than Nash (see section 6.3 below). Intuitively, fiscal policy is too contractionary in the Nash equilibrium. The leading monetary authority anticipates this inefficiency and expands monetary policy more under leadership than Nash. This raises the price level and eliminates the fiscal authority's need to tighten fiscal policy. As a result, fiscal policy is more expansionary and output is higher under monetary leadership than Nash.

6.2 Discretionary Policies and Fiscal Leadership

In this section we consider the case of fiscal leadership. After the private sector's expectations are set and the shocks are realized, the fiscal authority chooses x. With x fixed, the monetary authority chooses m. As usual, we solve this game by backward induction. This requires starting with the last player that, in this case, is the monetary authority.

The monetary authority minimizes the loss function (4) with x given; hence, the first-order condition with respect m is given by the MRF (13) of section 5. The fiscal authority minimizes the loss function (3) with respect to x, subject to (13). The first-order condition for fiscal leadership is:

$$\pi = \pi_F + \frac{\theta_F}{\theta_M\, b}\,(y - y_F) + \frac{\delta(1+\theta_M b^2)}{\theta_M\, b\, a}\,. \tag{21}$$

The outcome is found by solving the monetary reaction function (13) and the fiscal first-order condition (21). This gives the solution for y and π that we derive in appendix E.

The first-order condition (21) defines an upward sloping line passing through point A of Figure 1 that can be steeper or flatter than FRF depending on the realization of the stochastic parameters. Hence, fiscal leadership has either lower output and higher prices than Nash, or vice versa. Social losses are always lower under fiscal leadership than Nash.

6.3 Welfare Comparison of Discretionary Regimes

In this section we take the authorities' policy goals as given and we compare social welfare under the discretionary regimes (Nash, monetary and fiscal leadership) and the second-best allocation from an ex ante point of view. We wish to shed some light on whether a discretionary regime is preferable to the others independently of the realization of the shocks.

To compare social welfare under the alternative regimes, we evaluate

$$\Omega \equiv \int L_F - L_F^{SB}, \tag{22}$$

where L_F is the social loss under the considered discretionary regime and L_F^{SB} is the social loss in the second-best allocation. We evaluate Ω under the assumption that the parameters are deterministic.

The parameter values for our benchmark specification are reported in Table 1. The central bank is price-conservative with price target as in (19), but it has the same weight and target for output as the fiscal authority.

Table 2 shows the equilibrium values for output, price level, fiscal and monetary policies and Ω in the second-best allocation and in the three discretionary regimes for our benchmark economy. All three discretionary regimes have lower output and a higher price level than the second-best allocation; social losses are highest in the Nash equilibrium. With $\theta_F = \theta_M$ and $y_F = y_M$, they are exactly equal under monetary and fiscal leadership; we discuss this further below. Intuitively, the authority with leadership anticipates the suboptimality of the follower policy and partly offsets it. In the case of monetary leadership, the central bank anticipates that fiscal policy will be too tight and therefore runs a more expansionary monetary policy than under Nash. This raises the price level and discourages the fiscal authority from tightening fiscal policy too much in order to raise prices further. As a result,

$y_F = 1$	$y_M = 1$	$\pi_F = .05$	$\bar{y} = .94$	$\theta_F = 1$
$\theta_M = 1$	$a = 1$	$b = .5$	$c = -.5$	$\delta = .05$
$\pi_M = \pi_F - \theta_M b(y_M - \bar{y}) = .02$				

Table 1: Benchmark specification

	Second Best	*Nash*	*Monetary Leadership*	*Fiscal Leadership*
y	.95	.9375	.942	.94
π	.05	.05625	.0635	.055
x	.01	-.0025	.0023	0
m	.055	.055	.065	.055
Ω^X	0	.41	.31	.31

Table 2: Discretionary regimes

monetary leadership has more expansionary monetary and fiscal policies than Nash, thereby raising output and prices.

In the case of fiscal leadership, the fiscal authority knows that the central bank desires a lower price level than its own. To elicit a more expansionary monetary policy, the fiscal authority expands fiscal policy more under leadership than Nash, thereby raising output and lowering the price level.

How is the ranking between monetary and fiscal leadership affected by changes in the output and price goals, and the parameter values? In general, fiscal leadership becomes welfare superior to monetary leadership. In fact, our benchmark specification with equal output goals and the weights on them for the two authorities is the best case for monetary leadership.

When the central bank is output-conservative, hence $y_M < y_F$, and price-conservative as in (19), fiscal leadership is welfare superior to monetary leadership for all $\theta_M \leq \theta_F$. The intuition is simple. In anticipation of tighter monetary policy (due to the lower output goal), the fiscal authority with first-mover advantage expands fiscal policy more, thereby raising output and lowering the price level.

When the central bank is more price-conservative than (19), fiscal leadership is welfare superior to monetary leadership as long as $\theta_M < \theta_F$ and/or $y_M < y_F$. The logic behind this result is the same as before: fiscal policy is more expansionary under fiscal leadership because this reduces the price level and avoids monetary policy from being too tight. In terms of Figure 1, a conservative central bank has a flat MRF, along which a small reduction in the price level requires a large reduction in output; the fiscal authority will choose allocations on the MRF characterized by low prices and high output than vice versa.

When the central bank has preferences as in the benchmark specification, changes in the parameters a, b, c, δ leave social losses identical under monetary and fiscal leadership. This should not be surprising, as the price target for the central bank, which is the only difference in preferences between the two authorities, will change accordingly.

When the central bank has price-target (19) but is more conservative than the fiscal authority in the sense that $\theta_M < \theta_F$ and/or $y_M < y_F$, changes in the parameters a, b, c, δ affect the welfare ranking of fiscal and monetary leadership. More precisely, fiscal leadership dominates monetary leadership as long as a is not too small.[8] Intuitively, small values of a make fiscal policy ineffective with respect to output. Raising output above its natural rate therefore requires too large a fiscal expansion and too low a price level.

Fiscal leadership is better than monetary leadership for most values of b; however, if a is small and c is close to zero, fiscal leadership is superior only for low values of b. Intuitively, if c is close to zero, fiscal expansions do not reduce the price level and monetary policy is too tight under fiscal leadership. At the same time, low values of a and high values of b worsen the time-consistency problem of fiscal policy and make monetary leadership a better option.

Fiscal leadership is either equivalent or dominates monetary leadership for all values of δ.

7 Monetary Commitment

So long as the monetary rule has been credibly committed to, it does not matter whether fiscal policy is chosen before or after the actual monetary policy action is taken at step 4. The shocks are already realized, so the monetary action is fully predictable even if it has not been taken yet. The fiscal authority must act with this foreknowledge; therefore it is a follower even though its action may be taken earlier in calendar time. Thus questions such as whether fiscal lags are long are irrelevant given monetary commitment and fiscal discretion.

Since the monetary policy rule $m(z)$ is chosen at an earlier stage, its decision must be made using the logic of subgame perfectness that takes into account the action of the fiscal authority later on in the game. One would think that commitment to a full state-contingent monetary rule would allow the central bank to get close to its ideal outcome or, at least, to do better than the case where monetary policy is discretionary. It turns out that, as long as fiscal policy is discretionary, the monetary authority cannot improve upon the equilibrium that arises under monetary leadership with discretion. Hence, fiscal discretion destroys monetary commitment! As long as the central bank can move before the fiscal authority, commitment to a policy rule does not matter. The most that monetary commitment can achieve is to ensure the equivalent of first-mover advantage (if it exists) in the game at step 4.

Lately, much emphasis has been put on the importance of monetary rules to maintain inflation low and stable. This argument is thought to be particularly relevant for monetary unions, such as the EMU, where each government may engage in fiscal expansions to increase its own GDP expecting to pass the cost of its profligacy to other members in the form of higher inflation and interest rates. Our finding suggests that commitment to a monetary rule *not* accompanied by commitment to a fiscal rule is not enough.

To solve for the monetary rule chosen at step 2, we must use backward induction and

[8] Parameter configurations must satisfy the condition, derived in appendix A, that $a + bc > 0$.

start from the choice of fiscal policy at step 4 (b). The fiscal authority minimizes the loss function (3) with respect to x with m fixed. The first-order condition with respect to x is, once again, the FRF (12). One can therefore solve for fiscal policy as a function of the stochastic shocks, the monetary rule and private sector's expectations by substituting (1) and (2) into (12), and then output and price, as of step 1 and taking into account the choice of the fiscal authority. This is done in detail in appendix F.

At step 1, the monetary authority chooses the whole function $m(\cdot)$ to minimize the expected loss function

$$\int L_M(z) = \frac{1}{2}\int \left[\theta_M (y(z) - y_M)^2 + (\pi(z) - \pi_M)^2\right], \tag{23}$$

where $y(z)$, $\pi(z)$ and π^e are given by (F.6), (F.7), and (5) respectively. But the substitution of π^e into the objective complicates the algebra, because it then involves one integration inside another. We avoid this by regarding the monetary authority as if it had another choice variable, namely π^e, but its choice was subject to the constraint (5). The Lagrangean for this problem is as follows

$$\mathcal{L}_{\mathcal{M}} = \int \left\{\frac{1}{2}\left[\theta_M (y(z) - y_M)^2 + (\pi(z) - \pi_M)^2\right] + \lambda_M \pi(z)\right\} - \lambda_M \pi^e, \tag{24}$$

where λ_M is the Lagrangean multiplier.

The first-order condition with respect to the function $m(z)$ is given by

$$(y(z) - y_M) - \frac{\theta_F}{\theta_M}\left(\frac{a}{c} + b\right)(\pi(z) - \pi_M + \lambda_M) = 0. \tag{25}$$

The first-order condition with respect to π^e is given by

$$-\lambda_M - \int \frac{\theta_M\, b}{\theta_F \left(\frac{a}{c} + b\right)^2 + 1}\left[(y(z) - y_M) - \frac{\theta_F}{\theta_M}\left(\frac{a}{c} + b\right)(\pi(z) - \pi_M + \lambda_M)\right] = 0. \tag{26}$$

Using (25), the first-order condition (26) simplifies to

$$\lambda_M = 0.$$

When all the m are chosen ex-ante optimally, the rational expectations constraint is on the borderline of not binding. Using $\lambda_M = 0$, (25) becomes

$$(y(z) - y_M) - \frac{\theta_F}{\theta_M}\left(\frac{a}{c} + b\right)(\pi(z) - \pi_M) = 0, \tag{27}$$

which is equivalent to (20), the first-order condition for m in the case where monetary policy is discretionary with monetary leadership! In fact, the state-by-state outcomes can be found by solving the discretionary fiscal reaction function (12) and the monetary rule (27), which is done in appendix D. The outcome under monetary commitment is therefore exactly the same as the outcome under monetary discretion with monetary leadership for every realization of the shocks.

It is obvious that the rule for this fully optimal monetary policy $m(z)$ is going to be a very general nonlinear one in the state variables z. Much of the literature on monetary rules has imposed a condition of linearity so m is a linear function of the stochastic shocks and then calculated the expected loss and minimized it with respect to the coefficients of the linear function. We do not require linearity and solve a more general calculus of variations problem. Our monetary rule is not a linear function of z, and the reason is that even though the model is linear-quadratic, our stochastic shocks are not in general additive.

Fiscal discretion destroys the gains from monetary commitment because prices cannot be lowered without also lowering output. If fiscal policy is discretionary, monetary commitment must lie on the fiscal reaction function, so that the downward shift in the central bank's reaction function due to commitment reduces the price level at the cost of also reducing output. More precisely, in response to tighter monetary policy, the fiscal authority tightens its own policy so as to surprise expectations, which leads to lower output with no reduction in the price level relative to monetary leadership! A committed central bank is better off adopting the discretionary policy that would be chosen under monetary leadership.

In terms of Figure 1, the first-order condition (20) of the central bank with leadership goes thru its bliss point M. Shifting that reaction function down (by committing to a less expansionary monetary policy for all possible realizations of the stochastic shocks) so that it does not go thru the bliss point will make the central bank worse off. Hence, the central bank prefers not to commit to a policy rule.

In models where fiscal policy is non-strategic, as in section 5.1, monetary commitment eliminates the upward bias in prices without affecting output. However, this is not the case with strategic and discretionary fiscal policy: the upward bias in prices can only be eliminated at the cost of lower output. We find that this negates the advantage of monetary commitment.

The conservativeness of the central bank is a key factor for why monetary commitment is destroyed. If the term δx appeared in the loss function of the central bank, the optimal monetary rule would recognize the time inconsistency of fiscal policy and tighten accordingly. In that case, the Lagrangean multiplier of the rational expectations constraint is equal to $\int \delta b/a$, which is the same value it takes under commitment full commitment (see equation (11).

8 Fiscal Commitment

Now we consider the case where fiscal policy is committed at step 1 whereas monetary policy is discretionary and chosen at step 4 (a). Our exposition will be brief, since the logic by which the fiscal rule $x(z)$ is chosen is very much similar to that used in the previous section for monetary commitment.

The monetary authority minimizes the loss function (4) with respect to m with x fixed. The first-order condition with respect to m is, once again, the MRF (13). Then, one can solve for monetary policy as a function of the stochastic shocks, the fiscal rule and private sector's expectations by substituting (1) and (2) into (13), and then output and the price level, as of step 1 and taking into account the choice of the monetary authority. This is done in detail in appendix G.

The Lagrangean for the problem of the fiscal authority is as follows:

$$\mathcal{L}_{\mathcal{F}} = \int \left\{ \frac{1}{2} \left[\theta_F (y(z) - y_F)^2 + (\pi(z) - \pi_F)^2 + 2\delta x(z) \right] + \lambda_F \pi(z) \right\} - \lambda_F \pi^e, \tag{28}$$

where λ_F is the Lagrangean multiplier, $y(z), \pi(z)$ and π^e are given by (G.10), (G.11) and (5), respectively.

The first-order condition with respect to the function $x(z)$ is given by

$$(y(z) - y_F) \frac{\theta_F}{\theta_M b} - (\pi(z) - \pi_F + \lambda_F) + \delta \frac{1 + \theta_M b^2}{\theta_M b a} = 0. \tag{29}$$

The first-order condition with respect to π^e is given by

$$-\lambda_F - \int \frac{\theta_M b^2}{1 + \theta_M b^2} \left[(y(z) - y_F) \frac{\theta_F}{\theta_M b} - (\pi(z) - \pi_F + \lambda_F) \right] = 0. \tag{30}$$

Using (29), the first-order condition (30) simplifies to

$$\lambda_F = \int \frac{\delta b}{a} > 0. \tag{31}$$

Using (29), (13) and (31), one can solve for output and price; this is done in appendix G.

Fiscal commitment is equivalent to fiscal leadership for all realization of shocks without time inconsistency of fiscal policy. The first-order condition with fiscal commitment (29), is the same as the first-order condition with fiscal leadership (21), except for the term λ_F. Figure 2 shows the equilibrium with fiscal commitment and that with fiscal leadership. FLFOC, the first-order condition with fiscal leadership, goes thru point A; FCOM, the first-order condition with commitment, is parallel to FLFOC and shifted down by the Lagrangean multiplier of the rational expectations constraint λ_F. Since $\lambda_F > 0$, the rational expectations constraint is binding when all the x are chosen ex-ante optimally. More precisely, λ_F is the average upward bias in prices that arises with fiscal leadership at $y = \tilde{y}$. Commitment of fiscal policy eliminates this bias, thereby shifting the first-order condition from FLFOC to FCOM. Notice that FCOM passes thru point C and is therefore consistent with the second best.

An important result emerges here. If the central bank is appropriately conservative with price target as in (19), fiscal commitment delivers the second best. Figure 2 shows the MRF of such central bank, which goes thru point C; fiscal commitment occurs at the intersection of FCOM and MRF, which is point C and the second-best allocation.

Even though the fiscal authority is constrained to choose an allocation along the reaction function of the monetary authority, fiscal commitment is useful because it removes the

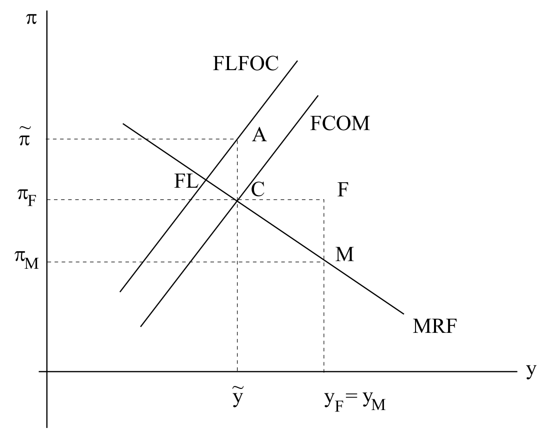

Figure 2: Fiscal commitment

excessive tightness of fiscal policy stemming from the desire to reduce deadweight losses and surprise expectations. Hence, monetary discretion does not destroy completely the gains of fiscal commitment. Further intuition can be obtained by looking at Figure 2. FLFOC does not go thru the second best, point C, because of the time-inconsistency of fiscal policy; at the same time, the equilibrium with fiscal commitment must lie on the MRF. Commitment of fiscal policy, in the sense of a downward shift of the fiscal reaction function FLFOC so that it goes thru point C, improves social welfare.

9 Institution Design and Welfare

If commitment to a policy rule is not an option, could monetary and fiscal institutions be designed so as to obtain the second best with discretionary policies? The answer is yes. In our setting, there are two different goal assignments that lead to the second-best allocation. First, in the presence of a time-consistency problem of monetary and fiscal policies, the second best is obtained by giving the same socially optimal output objective and the same conservative price objective to both authorities. More precisely, some simple algebra shows that the following loss function for both the monetary and the fiscal authorities:

$$\tilde{L}_F = \frac{1}{2}\left[(\pi - \tilde{\pi}_F)^2 + \theta_F(y - y_F)^2 + 2\delta x\right],$$

with

$$\tilde{\pi}_F = \pi_F - \frac{\delta b}{a}$$

achieves the second best as the Nash equilibrium. Intuitively, price conservativeness takes care of the time-consistency problem of monetary and fiscal policies; at the same time, the fact that both authorities have identical objectives eliminates any suboptimal interaction between their policies. In terms of Figure 1, $\tilde{L}_F$ shifts the bliss point of the government from F to M. Hence, the FRF goes thru C, which is the Nash equilibrium.

The other institutional design that delivers the second best makes each authority responsible for only one goal. More precisely, the central bank should care only about the price level being at its socially optimal level and minimize the loss function

$$L_M^* = \frac{1}{2}\,(\pi - \pi_F)^2. \tag{32}$$

The fiscal authority should care only about output being at its efficient level and minimize the loss function

$$L_F^* = \frac{1}{2}\left[(y - y_F)^2 + 2\delta x\right]. \tag{33}$$

In terms of Figure 1, under this goal assignment the MRF becomes the horizontal line $\pi = \pi_F$, the FRF becomes the vertical line $y = \tilde{y}$, and their intersection is point C, which is the Nash equilibrium.

10 Concluding Comments

Any policy implications of such a simple first pass at a large problem must be tentative. With that proviso, we would like to suggest some implications of our results for the design of monetary and fiscal institutions.

In the absence of a time-consistency problem for monetary and fiscal policy, extra conservatism of the monetary authority is a bad idea. Independence of a central bank means that fiscal and monetary policies will be chosen by different authorities in a non-cooperative game that results in a Nash equilibrium; if the fiscal and monetary authorities have different goals, the non-cooperative game can result in a Nash equilibrium that is extreme in both the dimensions of output and inflation. Without a time-consistency problem, both the monetary and the fiscal authority should have identical output and price goals that coincide with the socially optimal ones.

If monetary and fiscal policies suffer from time-inconsistency, the two authorities' ideal points for the two targets should once again coincide. More precisely, the output goal should be the socially efficient level of output; the price goal should be conservative, i.e. lower, than the socially optimal one. What is important, the output and inflation objectives of the two authorities should be the same. Alternatively, monetary policy should only the target an appropriately conservative price target whereas fiscal policy should only target the efficient level of output.

Giving first-mover advantage to the fiscal authority improves social welfare over Nash and, in most circumstances, over monetary leadership. The resulting equilibrium, however, is not second best.

When policies can be chosen after stochastic shocks are realized, policymaking can be discretionary, or rule-governed in the sense of precommitment to a function that specifies the policy action to be taken as a function of the realization of the shock. The merits of commitment to a monetary rule are well understood from models that consider monetary policy in isolation. We find that if fiscal policy remains discretionary, then the monetary rule must recognize the fiscal reaction function as a constraint in each state of the world, with the result that the value of monetary commitment is completely negated - the optimal monetary rule is the same as monetary leadership in each state of the world (for each realization of the shocks). Therefore it may not be worth incurring the political cost of putting in place any mechanisms of monetary commitment, unless fiscal policy is also committed.

If fiscal policy is committed while monetary policy is discretionary, monetary discretion cannot offset the deadweight loss created by fiscal policy and therefore cannot destroy fiscal commitment completely.

If the monetary and fiscal authorities' ideal point in the output-inflation space, and its tradeoff parameter between the two objectives, can be chosen in advance, then this choice can be made to affect the outcome point and the socially optimal and feasible allocation can be achieved by making both authorities equally and optimally conservative with respect to inflation. Alternatively, the socially optimal and feasible allocation can be achieved by making the monetary authority care solely about an appropriately conservative price target and by making the fiscal authority care solely about the efficient level of output.

Appendix

C Nash equilibrium

Written in matrix notation, we have

$$\begin{bmatrix} \theta_F\,(b+a/c) & 1 \\ \theta_M b & 1 \end{bmatrix} \begin{bmatrix} y \\ \pi \end{bmatrix} = \begin{bmatrix} \pi_F \ + \theta_F\,(b+a/c)\, y_F \ - \delta/c \\ \pi_M \ + \theta_M\, b\, y_M \end{bmatrix}$$

The determinant of the matrix on the left hand side is

$$\Omega \equiv \theta_F(\frac{a}{c} + b) - \theta_M b.$$

Then the solution exists as long as Ω is different from zero, which is the case almost surely (for probability one of realizations of shocks). The solution is given by

$$\begin{bmatrix} y \\ \pi \end{bmatrix} = -\frac{1}{\Omega} \begin{bmatrix} 1 & -1 \\ -\theta_M\, b & \theta_F\,(b+a/c) \end{bmatrix} \times \begin{bmatrix} \pi_F \ + \theta_F\,(b+a/c)\, y_F \ - \delta/c \\ \pi_M \ + \theta_M\, b\, y_M \end{bmatrix} \tag{C.1}$$

Write (1) and (2) also in vector-matrix notation:

$$\begin{bmatrix} a+bc & b \\ c & 1 \end{bmatrix} \begin{bmatrix} x \\ m \end{bmatrix} = \begin{bmatrix} y - \overline{y} + b\,\pi^e \\ \pi \end{bmatrix}$$

This has the solution

$$\begin{bmatrix} x \\ m \end{bmatrix} = \frac{1}{a} \begin{bmatrix} 1 & -b \\ -c & a+bc \end{bmatrix} \begin{bmatrix} y - \overline{y} + b\,\pi^e \\ \pi \end{bmatrix} \tag{C.2}$$

The values of x, m can then be obtained substituting y, π from (C.1).

D Monetary Leadership

Written in vector-matrix notation, we have

$$\begin{bmatrix} \theta_M & -\theta_F\,(b + a/c) \\ \theta_F\,(b + a/c) & 1 \end{bmatrix} \begin{bmatrix} y \\ \pi \end{bmatrix} = \begin{bmatrix} \theta_M\, y_M - \theta_F\,(b + a/c)\,\pi_M \\ \theta_F\,(b + a/c)\, y_F + \pi_F \, - \delta/c \end{bmatrix}$$

This has the solution

$$\begin{bmatrix} y \\ \pi \end{bmatrix} = \frac{1}{\theta_M + \theta_F^2\,(b + a/c)^2} \begin{bmatrix} 1 & \theta_F\,(b + a/c) \\ -\theta_F\,(b + a/c) & \theta_M \end{bmatrix} \tag{D.3}$$

$$\times \begin{bmatrix} \theta_M\, y_M - \theta_F\,(b + a/c)\,\pi_M \\ \theta_F\,(b + a/c)\, y_F + \pi_F \, - \delta/c \end{bmatrix}$$

The values of x, m can then be obtained substitituting from (D.3) in (C.2).

E Fiscal Leadership

Written in vector-matrix notation, we have

$$\begin{bmatrix} \theta_M b & 1 \\ -\theta_F & \theta_M\, b \end{bmatrix} \begin{bmatrix} y \\ \pi \end{bmatrix} = \begin{bmatrix} \theta_M\, b\, y_M + \, \pi_M \\ -\theta_F\, y_F + \theta_M\, b\, \pi_F \, + \delta(1 + \theta_M\, b^2)/a \end{bmatrix}$$

This has the solution

$$\begin{bmatrix} y \\ \pi \end{bmatrix} = \frac{\theta_M\, b}{\theta_M^2\, b^2 + \theta_F} \begin{bmatrix} \theta_M b & -1 \\ \theta_F & \theta_M\, b \end{bmatrix} \tag{E.4}$$

$$\times \begin{bmatrix} \theta_M\, b\, y_M + \, \pi_M \\ -\theta_F\, y_F + \theta_M\, b\, \pi_F \, + \delta(1 + \theta_M\, b^2)/a \end{bmatrix}$$

F Monetary Commitment

Substituting (1) and (2) into (12), we obtain

$$x(z) = \frac{1}{c\,[\theta_F (b + a/c)^2 + 1]} \left\{ - \left[\theta_F b \, \left(\frac{a}{c} + b \right) + 1 \right] m(z) \right. \tag{F.5}$$

$$\left. -\theta_F \left(\frac{a}{c} + b \right) [\overline{y} - y_F - b\, \pi^e] + \pi_F - \frac{\delta}{c} \right\}.$$

Output and prices, as of step 2 and taking into account the choice of the fiscal authority at step 4 (b), are

$$y(z) = \frac{1}{\theta_F (b + a/c)^2 + 1} \left\{ -\frac{a}{c}\; m(z) + \overline{y} - b\, \pi^e + \theta_F \left(\frac{a}{c} + b \right)^2 \left[y_F + \frac{\pi_F - \delta/c}{\theta_F\,(a/c + b)} \right] \right\}, \tag{F.6}$$

and

$$\pi(z) = \frac{1}{\theta_F (b + a/c)^2 + 1} \left\{ \theta_F \frac{a}{c} \left(\frac{a}{c} + b \right) m(z) - \theta_F \left(\frac{a}{c} + b \right) [\bar{y} - y_F - b\pi^e] + \pi_F - \frac{\delta}{c} \right\}. \tag{F.7}$$

Proceeding by backward induction, we now consider the private sector that sets its expectations rationally at step 3. More precisely, expectations are

$$\pi^e = \int \pi(z), \tag{F.8}$$

with $\pi(z)$ given by (F.7) and the integral is four-dimensional with respect to the joint distribution of z.

G Fiscal Commitment

Substituting (1) and (2) into (13), we obtain

$$m(z) = \frac{1}{1 + \theta_M b^2} \{ \pi_M - \theta_M \, b(\bar{y} - b\,\pi^e - y_M) - x(z)[c + \theta_M \, b(a + b\,c)] \} \tag{G.9}$$

Output and prices, as of step 1 and taking into account the choice of the monetary authority at step 4 (a), are

$$y(z) = \frac{1}{1 + \theta_M b^2} \left[\bar{y} + b(\pi_M - \pi^e) + \theta_M \, b^2 y_M + a\,x(z) \right] \tag{G.10}$$

and

$$\pi(z) = \frac{1}{1 + \theta_M b^2} \left[\pi_M - \theta_M \, b(\bar{y} - y_M) + \theta_M \, b^2 \pi^e - \theta_M \, b\,a\,x(z) \right] \tag{G.11}$$

The private sector sets its expectations rationally at step 3 by taking the expected value of (G.11).

Using (29), (13) and (31), we can solve for output and the price level as a function of the parameters of the model

$$y(z) = \frac{1}{\theta_F + \theta_M^2 \, b^2} \left[\theta_F y_F + \theta_M^2 \, b^2 \, y_M + \theta_M \, b(\pi_M - \pi_F + \int \delta b/a) - \delta(1 + \theta_M \, b^2)/a \right] \tag{G.12}$$

and

$$\pi(z) = \frac{1}{\theta_F + \theta_M^2 \, b^2} \left[\theta_F \pi_M + \theta_M \, b\,\theta_F (y_M - y_F) + \theta_M^2 \, b^2 (\pi_F - \int \delta b/a) + \delta\,\theta_M \, b(1 + \theta_M \, b^2)/a \right]. \tag{G.13}$$

Substituting the price target (18) into (G.12) and (G.13), one obtains that

$$\int y = \int y_F - \frac{\delta}{\theta_F \, a}, \qquad \int \pi = \pi_F.$$

If the central bank is appropriately conservative as in (18), fiscal commitment delivers on average the second-best allocation.

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