CENTRAL BANK REPUTATION AND THE MONETIZATION OF DEFICITS: THE 1981 ITALIAN MONETARY REFORM

GUIDO TABELLINI*

In 1981 the Bank of Italy was freed from the obligation to purchase the unsold public debt at the Treasury auctions. Since then, the Bank of Italy has reduced debt monetization. The paper seeks to explain this policy shift by analyzing a game between the monetary and fiscal authorities. The fiscal authority is imperfectly informed about the central bank preferences. An equilibrium exists in which the central bank does not monetize, so as to establish a reputation of being independent. Monetization raises fiscal deficits and may raise public debt relative to a non-accommodative policy.

I. INTRODUCTION

In July 1981 Italy underwent a monetary regime change: the Bank of Italy was freed from the obligation to purchase all the unsold public debt at the Treasury auctions. Before July 1981 the Treasury set the minimum auction price and the Bank of Italy had to buy all the public debt not taken up by the market. The Italian central bank could then resell the public debt in a well developed secondary market.[1] But by so doing, it would drive up interest rates and it would generally incur a capital loss.

Thus, the "divorce" between the Bank of Italy and the Treasury, as the institutional reform was called in the Italian press, had the following consequences. First of all, it deprived the Treasury of an implicit subsidy on the interest paid on public debt. Secondly, it shifted the political responsibility for the level of interest rates from the monetary to the fiscal authorities. These two consequences were anticipated at the time when the divorce was implemented, and were the main motivations for its adoption; see Salvemini [1983]. It was hoped that the new incentive structure would bring about a more moderate fiscal policy and a less accommodative monetary policy.

At least one of these hopes was born out by the subsequent economic events. Even though fiscal policy in Italy has recently shown only very small signs of moderation, the course of monetary policy has undergone a substantial shift since 1981. The percentage of public debt held by the Bank of Italy over total

* University of California, Los Angeles. I wish to thank Richard Sweeney, Luca Molteni and two anonymous referees for very helpful comments on previous versions of this paper. The responsibility for all remaining errors is my own.

1. In this respect, the Italian reform differs crucially from the Fed-Treasury Accord that occurred in the U.S. in 1951; before the Accord, the Fed was obliged to support the price of public debt both in the primary and in the secondary market. The U.S. Accord thus relieved the Fed from a portfolio constraint. In the case of Italy, there was no such constraint to begin with.

Economic Inquiry
Vol. XXV, April 1987, 185–200

TABLE I
Stock of Public Debt Held by the Bank of Italy*

1978	.29
1979	.23
1980	.24
1981	.24
1982	.22
1983	.18
1984	.17
1985	.16

* Percent of public debt held by Bank of Italy and Ufficio Italiano Cambi over total public debt, at the end of each year.
Source: Bank of Italy.

public debt has dropped substantially, from 24 percent in 1981 to 16 percent in 1985 (see Table I); at the same time, the real interest rate was allowed to increase from below −3 percent in 1981 to an unprecedented high of approximately 7 percent in mid-1985.

Such a huge policy shift is difficult to explain just on the grounds that were mentioned above, namely that the divorce relieved the Bank of Italy from political pressures to keep interest rates low. Even after July 1981, the Bank of Italy continued to frame its monetary policy mainly in the form of interest rate objectives, and a policy of strict targeting some monetary aggregates was always explicitly rejected by the Italian monetary authorities. Nor can it be argued that the divorce simply freed the Bank of Italy from a binding portfolio constraint; before the divorce the Italian monetary authorities could already resell public debt in a well developed secondary market, so as to achieve the desired degree of debt monetization.

A more appealing explanation of the monetary policy shift is that the divorce indeed changed the incentive structure of the Italian monetary authorities. But it did so through a more subtle channel, whose relevance was probably underestimated at the time when the reform was drafted. Specifically, the institutional reform raised some uncertainty, in financial markets and in the Treasury, about the extent of future debt monetization. This uncertainty in turn created a new incentive for the Bank of Italy to establish a reputation of independence and unwillingness to monetize the stock of public debt in circulation, so as to force a reduction in fiscal deficits by the Treasury.

This paper investigates in detail this explanation of the recent Italian events, by analyzing a game theoretic model in which reputational effects influence the selection of monetary and fiscal policy rules. The model assumes that the Bank of Italy and the Treasury have conflicting objectives: both would like to see a smaller public debt in circulation; however, the Bank of Italy would like this to occur through a reduction in fiscal deficits, whereas the Treasury would rather have an increase in the degree of monetization. This conflict between the two policymaking authorities is a crucial factor in understanding the chain

of events that led to the Italian monetary reform and to the subsequent monetary policy shift, and is clearly reflected in the public statements of the Italian authorities. At a more abstract and general level, the conflict can be explained with reference to the fact that, as in most industrial countries, the two authorities face different political incentives and constraints. The central bank is not elected and it generally enjoys some independence from the fiscal authority, while the fiscal authority is generally directly responsible for its actions to the electorate and to various political constituencies.

The model implies that the more credible is the commitment of the Bank of Italy to a policy of no debt monetization, the smaller is the size of fiscal deficits net of interest payments. This inverse relationship between fiscal deficits and the credibility of a nonaccommodative monetary policy is what gives the Bank of Italy an incentive to establish its reputation of being independent. The mechanism of reputation formation is described in the model with reference to the learning process of the Treasury about the true nature of the Bank of Italy. An accommodative monetary policy reveals to the Treasury that the Bank of Italy is also going to monetize in the future. Vice versa, a nonaccommodative monetary policy can enhance or maintain the Bank of Italy reputation of being independent.

There are two main results of the paper. (a) An equilibrium exists in which, in the early stage of the game, these reputational incentives are large enough to sustain a monetary policy less accommodative than the one that would be chosen in a world of complete information. This equilibrium exists even if the uncertainty introduced by the divorce is infinitesimal. (b) The existence of this uncertainty changes the consequences of accommodative monetary policies. If the Bank of Italy monetizes in the early stages of the game, it signals to the Treasury that it is also going to monetize in the future. This causes larger fiscal deficits and, for some parameter values, it can bring about a larger stock of public debt outstanding.

The first result lends support to the view that the main effect of the Italian monetary reform was indirectly to change the incentive structure of the Bank of Italy, by raising uncertainty about its future behavior. The second result casts doubt on the popular policy prescription that, in the face of large fiscal deficits and in order to avoid excessive crowding out of capital accumulation, the central bank should follow a rule of debt monetization. In a situation like the one that emerged in Italy after 1981, such an accommodative monetary policy could backfire by leading to larger fiscal deficits and to larger (rather than smaller) public debt outstanding.

The outline of the paper is as follows. Section II describes the basic model; section III characterizes the general solution; section IV describes the Treasury learning process. Section V derives the fiscal policy reaction function. Section VI characterizes the equilibrium; it is a perfect Bayesian Nash equilibrium in which both players choose feedback strategies. Section VII contains a discussion and some concluding remarks.

II. THE MODEL

The key aspects of the Italian monetary reform concern the strategic interaction between the two policymakers in the choice of public financial policies. These aspects are fully captured in a very simple way by focusing exclusively on the dynamics of the government budget constraint, and by leaving the private sector out of the picture. Thus the model presented in this section differs substantially from some of the recent literature on games of macroeconomic policy, which instead has emphasized the strategic interaction between one or both policymakers and the private sector.[2] Modifying the simple model presented below by adding a strategic role for the private sector may add new insights into other issues, but should not affect the nature of the results concerning the interaction between the two policymakers.

The lack of an explicit description of the private sector behavior is reflected in two special features of the model presented below, which greatly simplify the analysis: the linearity of the law of motion of public debt, and the particular specification of the loss functions of the two policymakers.

The law of motion of public debt is given by the government budget constraint, which can be written as

$$d_{t+1} = \eta d_t + f_t - m_t \tag{1}$$

where all variables have been divided by nominal income, and where $d_t \equiv$ stock of nominal public debt outstanding at the beginning of period t, $m_t \equiv$ creation of monetary base against liabilities of the Treasury, $f_t \equiv$ fiscal deficits net of interest payment. The parameter η can be shown to equal $(1 + r)/(1 + g)$, where $r \equiv$ real rate of interest, net of taxes and $g \equiv$ rate of growth of real income. The hypothesis that η is a parameter implies that there is a flat demand for public debt. This assumption is needed in order to have linear dynamics, and can be interpreted as saying that the economy is small and faces perfect international capital markets.[3]

The loss functions of both policy makers are taken to be quadratic in the state variable, d, and in the policy instruments, m and f. Thus, this is a discrete linear-quadratic dynamic game, for which a closed form solution can be found. The loss functions postulated below can be thought of as a quadratic approximation to more general loss functions. They differ from those often used in the theory of economic policy in one respect: they are defined directly on the policy instruments that enter the government budget constraint, rather than on more remote macroeconomic objectives. This specification is consistent with the main goal of the paper, namely to analyze the conflict between the two policymakers over the determination of the time path of public debt.[4] However, it presupposes that each policymaker considers the relationship between its instruments and the ultimate macroeconomic targets as invariant to changes in the instruments of the other policymaker.

Specifically, it is assumed that the central bank (CB) chooses m_t to minimize

$$L^M = \sum_{t=1}^{T} \beta^t[(m_t - \bar{m})^2 + \tau d_t^2] + \beta^{T+1}\tau d_{T+1}^2 \tag{2}$$

$$1 > \beta > 0, \qquad \tau > 0$$

subject to the government budget constraint, equation (1), to an initial condition $d_1 = \bar{d} > 0$, and to some hypothesis (yet to be specified) about the process generating f_t. The fiscal authority (FA) chooses f_t to minimize

$$L^F = \sum_{t=1}^{T} \gamma^t[(f_t - \bar{f})^2 + \lambda d_t^2] + \gamma^{T+1}\lambda d_{T+1}^2 \tag{3}$$

$$1 > \gamma > 0, \qquad \lambda > 0$$

also subject to the government budget constraint, to $d_1 = \bar{d}$, and to some hypothesis about m_t.

Equation (2) states that the CB attempts to minimize the deviations of changes in the domestic component of base money relative to nominal income from a given constant value, $\bar{m}$, and deviations of the stock of outstanding public debt from a desired value, for notational convenience taken to be zero. The parameter τ indicates the relative weight that the CB assigns to the two objectives. Similarly, equation (3) states that the FA attempts to minimize deviations of fiscal deficits net of interest payments from a given value, $\bar{f}$, and deviations of the stock of outstanding public debt from zero. The parameter λ indicates the relative weight assigned by the FA to the two objectives. The rates of time preference, β and γ, need not be equal to each other.

The final objectives of monetary and fiscal policy can be thought of as being implicit in the desired values for m, f and d. The target for m is presumably determined with reference to the desired rate of growth of nominal income or prices, or with reference to balance of payments targets. The preferences about f, the value of fiscal deficits net of interest payments, could reflect both standard macroeconomic objectives and political considerations.

The preferences about d, for both fiscal and monetary authorities, can be

2. An up-to-date survey of this literature is found in Cuckierman [1985]. The issue of central bank reputation in a game against private agents in the labor market is taken up by Backus and Driffill [1985], Barro [1986], Tabellini [1985a, 1985b]. Alesina and Tabellini [1985] study the issue of time consistency of monetary and fiscal policy in a repeated game between the central bank, the fiscal authority and the labor markets; but they have no public debt and no analysis of reputational incentives. Lucas and Stokey [1983], Persson, Persson and Svensson [1987], and Turnovsky and Brock [1980] study the time consistency of optimal financial policies; but they assume that the two policymakers have the same objective function, and neglect reputational issues. Finally, Tabellini [1986] analyzes a continuous time version of the model discussed in this paper, but again there is no analysis of reputational incentives in the selection of monetary and fiscal policies.

3. In this respect, the model does violence to the reality of the Italian economy, where controls on capital outflows have been in existence since the mid-1970s. Alternatively, equation (1) can simply be regarded as a local approximation of a nonlinear law of motion for public debt.

4. See Pindyck [1976] for a game theoretic analysis of the coordination of monetary and fiscal policies in the pursuit of standard macroeconomic objectives.

justified simply by appealing to the fact that, in the absence of lump sum taxes, a larger stock of public debt implies larger tax distortions in order to pay interest on the debt. Moreover, whenever the interest rate fluctuates, the fluctuations of taxes needed to pay for the debt are larger the larger is the stock of public debt outstanding. In addition, higher levels of d can be associated with lower rates of capital accumulation or with higher levels of external debt—see for instance Blanchard [1985]. The assumption that the desired value of d is the same for both players simplifies notations and computations, with practically no loss of generality. Moreover, it allows τ to be interpreted as the extent to which the CB is independent from the FA. For $\tau \to \infty$, monetary policy has the only role of financing a budget deficit exogenously chosen by the fiscal authorities. With $\tau = 0$, we have an independent central bank absolutely committed to pursuing its intermediate monetary target.

The model could be modified by adding some preferences for money growth in the loss function of the FA, or some preferences about budget deficits in the loss function of the CB. This modification would not change the nature of the results, as long as the model retained its basic feature, namely that both players would like to see a reduction in the stock of public debt outstanding; but the CB would like this to occur mainly through a reduction in fiscal deficits, whereas the FA would like it to come about mainly through an increase in debt monetization.

III. GENERAL SOLUTION OF THE GAME UNDER COMPLETE INFORMATION

This section describes the general solution to the model illustrated in the previous pages. For now, it is assumed that both players are completely informed about the rules of the game. The results derived here are then used in sections V and VI to characterize the equilibrium of the game when the FA has incomplete information about the CB loss function.

Throughout the paper, I consider only the case in which both players move simultaneously and cannot commit to a sequence of actions but reoptimize at each stage of the game. In other words, I consider only the feedback-Nash equilibrium. This choice is dictated in part by the institutional setting in which monetary and fiscal policy decisions are taken, in part by technical considerations. Specifically, the hypothesis that both players choose among feedback strategies reflects the fact that in Italy, as in most industrial countries, neither policymaker can undertake a commitment to a path of future actions. The Nash hypothesis that both players move simultaneously is made to simplify the analysis, despite the fact that the decision process behind the determination and implementation of budget deficits is longer and more inflexible than the decision process of the monetary authorities. Modelling the FA as the Stackelberg leader in the game, to reflect more accurately the institutional setting, would complicate the characterization of the equilibrium but would not alter the nature of the results.

Appealing to Bellman's optimality principle, the indirect loss functions of the two policymakers can be written as

$$V_t^M(d_t) = \frac{1}{2}\,\underset{m_t}{\mathrm{Min}}[(m_t - \bar{m})^2 + \tau d_t^2] + \beta V_{t+1}^M(d_{t+1}) \tag{4}$$

$$V_t^F(d_t) = \frac{1}{2}\,\underset{f_t}{\mathrm{Min}}[(f_t - \bar{f})^2 + \lambda d_t^2] + \gamma V_{t+1}^F(d_{t+1}). \tag{5}$$

Making use of equation (1), the first order conditions for an optimum are

$$m_t = \bar{m} + \beta V_{t+1}'^M \tag{6}$$

$$f_t = \bar{f} - \gamma V_{t+1}'^F \tag{7}$$

where $V_{t+1}'^M$ and $V_{t+1}'^F$ are the solution to the following recursions:

$$V_{t+1}'^M = \tau d_{t+1} + \beta[\eta + (\partial f_{t+1}/\partial d_{t+1})]V_{t+2}'^M \tag{8}$$

$$V_{t+1}'^F = \lambda d_{t+1} + \gamma[\eta - (\partial m_{t+1}/\partial d_{t+1})]V_{t+2}'^F \tag{9}$$

with terminal conditions $V_{T+1}'^M = \tau d_{T+1}$, $V_{T+1}'^F = \lambda d_{T+1}$. In deriving equations (6) and (7), the Nash hypothesis that both players take as given the contemporaneous action of the opponent was imposed. The terms $\partial f_{t+1}/\partial d_{t+1}$, $\partial m_{t+1}/\partial d_{t+1}$ on the right hand side of (8) and (9) follow from the hypothesis that both players choose among feedback strategies, thereby taking into account the effect of the state variable on future actions of the opponent. Note that by computing the solution by means of a dynamic programming method, a time consistency condition on the optimal policy rules is automatically imposed.

The solution to equations (6)–(9) can be computed recursively, working backwards from the last period of the game to the first one, for instance as in Basar and Olsder [1982]. The recursive solution of the FA decision rule is characterized in section V below. The derivation of the complete solution is available from the author upon request.

Before turning to the game of incomplete information, the following feature of the general recursive solution to equations (6)–(9) should be noted: if the CB is completely independent, that is, if $\tau = 0$ in equation (2), then $V_{T+1}'^M = 0$; working backwards from (8) and using (6) we then have $m_t = \bar{m}$ for all t. Thus, as expected, a completely independent CB will never deviate from its monetary target, $\bar{m}$, irrespective of the size of public debt in circulation.

IV. THE FISCAL AUTHORITY LEARNING PROCESS

One consequence of the divorce between the Bank of Italy and the Treasury must have been to create some uncertainty on the part of the Treasury about the future behavior of the Bank of Italy. The easiest way to introduce this uncertainty in the present model is to assume that the true value of τ, the degree of CB independence, is unknown to the FA. For simplicity and without loss of generality, suppose that when the game begins, the FA assigns a prior probability P to the event that $\tau = 0$, and a probability $(1 - P)$ to the event that $\tau = \bar{\tau} > 0$. P and the structure of the model as specified in sections II and III are "common knowledge."

If $\tau = 0$, then the CB is completely independent from the FA and, as shown at the end of section III, it sets $m_t = \bar{m}$ in each period. If instead $\tau = \bar{\tau} > 0$, then in each period of the game the CB can either pretend to be independent and set $m_t = \bar{m}$, or it can monetize some of the debt and set m_t according to the reaction function given in equations (6) and (8) with $\bar{\tau}$ replacing τ.

Let $P_t = \text{prob}(\tau = 0)$ be the FA prior beliefs at time t, and let $Q_t = \text{prob}(m_t = \bar{m})$ and $P_t^* = \text{prob}(m_t = \bar{m}/\tau = \bar{\tau})$. Thus, Q_t is the *unconditional* probability, as perceived by the FA at time t, that the CB will not accommodate in period t; and P_t^* is the *conditional* probability that the CB will not accommodate in period t, given that it is not independent (i.e., given that $\tau = \bar{\tau}$). It follows from these definitions that

$$Q_t = P_t + (1 - P_t)P_t^*. \tag{10}$$

After each stage of the game has been played, the FA observes m_t and revises its prior probability about the true value of τ according to Bayes rule:

$$\begin{aligned} P_{t+1} &= \text{prob}(\tau = 0/m_t) \\ &= [\text{prob}(m_t/\tau = 0)\cdot P_t]/ \\ &\qquad [\text{prob}(m_t/\tau = 0)\cdot P_t + \text{prob}(m_t/\tau = \bar{\tau})\cdot(1 - P_t)]. \end{aligned} \tag{11}$$

Since, as shown at the end of section III, $\text{prob}(m_t \neq \bar{m}/\tau = 0) = 0$, $\text{prob}(m_t = \bar{m}/\tau = 0) = 1$, and recalling that $P_t^* = \text{prob}(m_t = \bar{m}/\tau = \bar{\tau})$, equation (11) can be rewritten as

$$\begin{aligned} P_{t+1} &= 0 && \text{if} \quad m_t \neq \bar{m} \qquad \text{(i)} \\ P_{t+1} &= P_t/[P_t + (1 - P_t)P_t^*] && \text{if} \quad m_t = \bar{m}. \qquad \text{(ii)} \end{aligned} \tag{12}$$

This revised probability P_{t+1}, together with the existing stock of public debt, d_{t+1}, is a sufficient statistic for the history of the game up to period $t + 1$; it is then natural to identify P_{t+1} with a measure of the CB "reputation," as in Wilson [1986] and in Kreps and Wilson [1982]. If the CB accommodates (i.e., if m_t deviates from $\bar{m}$), it destroys its reputation, since it reveals to the FA that it is not independent (i.e., that $\tau \neq 0$); hence, according to (12.i), $P_{t+1} = 0$. If instead the CB refuses to monetize (i.e., if $m_t = \bar{m}$), it could either be that the CB is truly independent or that it is pretending to be so, in order to maintain or enhance its reputation. The relevant posterior probability, then, depends on P_t^*, the probability that a nonindependent CB sets $m_t = \bar{m}$. In equilibrium, P_t^* must be consistent with the optimal behavior of the CB. In section VI below the value taken by P_t^* will be deduced from the CB optimization problem. Before then, the optimization problem of the FA has to be solved.

V. THE OPTIMIZATION PROBLEM OF THE FISCAL AUTHORITY

At the beginning of each period, the FA selects f_t so as to minimize its expected loss, subject to the conjecture that the CB sets $m_t = \bar{m}$ with probability Q_t and that it accommodates with probability $(1 - Q_t)$.

Let d_{t+1}^N, d_{t+1}^A be the stock of public debt outstanding at the beginning of period $t + 1$, given that in period t the CB has set $m_t = \bar{m}$, and given that it has accommodated, respectively. Then, using (1) and (6), we have

$$d_{t+1}^N = \eta d_t + f_t - \bar{m} \tag{13}$$

$$d_{t+1}^A = \eta d_t + f_t - \bar{m} - \beta V_{t+1}^{\prime M}, \qquad V_{t+1}^{\prime M} > 0 \tag{14}$$

where $V_{t+1}^{\prime M}$ is given in (8), with $\tau = \bar{\tau}$ in it.

The FA minimizes the loss function described in equation (5), given that $d_{t+1} = d_{t+1}^N$ with probability Q_t and that $d_{t+1} = d_{t+1}^A$ with probability $(1 - Q_t)$. Taking the first order conditions of (5) with respect to f_t subject to this uncertainty about the CB behavior, with Q_t taken as given, and making use of (13) and (14), we can replace (7) with

$$f_t = \bar{f} - \gamma Q_t V_{t+1}^{\prime F}(d_{t+1}^N) - \gamma(1 - Q_t)V_{t+1}^{\prime F}(d_{t+1}^A) \tag{15}$$

where $V_{t+1}^{\prime F}$ is the solution to the following recursion:

$$\begin{aligned} V_{t+1}^{\prime F} = \lambda d_{t+1} &+ \gamma\eta Q_{t+1} V_{t+2}^{\prime F}(d_{t+2}^N) + \gamma(1 - Q_{t+1})V_{t+2}^{\prime F}(d_{t+2}^A) \\ &\cdot(\eta - \beta\partial V_{t+2}^{\prime M}/\partial d_{t+1}) \end{aligned} \tag{16}$$

with terminal condition $V_{T+1}^{\prime F} = \lambda d_{T+1}$.[5] The solution to (15) and (16) can be computed recursively together with the solution to (8), (13) and (14), starting from the last period of the game and moving backwards. After some tedious algebra, such a solution can be characterized as follows.

$$f_t^* = \bar{f} - g_t(Q_t), \qquad g_t(Q_t) > 0 \tag{17}$$

where $g_t'(Q_t) > 0$ if $d_{t+i} > 0$, $i > 0$ and if $\bar{f} > \bar{m}$.[6]

Thus if public debt exceeds its desired value in current and future periods, the size of fiscal deficits is inversely related to the CB reputation. By enhancing its reputation, the CB can bring about smaller fiscal deficits; and vice versa, if its reputation is destroyed, fiscal deficits will increase. The intuitive explanation of this result is simple. If fiscal deficits are more unlikely to be monetized by the CB, the FA will be forced to undertake more moderate behavior, in order to avoid further increases in the stock of public debt.

5. The derivation of equations (15) and (16) is analogous to that of equations (7) and (9) in Section III. Specifically, equation (13) has been used to set $\partial d_{t+2}^N/\partial d_{t+1} = \eta$ on the right-hand side of (16); and equation (14) has been used to set $\partial d_{t+2}^A/\partial d_{t+1} = [\eta - \beta(\partial V_{t+2}^{\prime M}/\partial d_{t+1})]$ on the right-hand side of (16).

6. The condition that $\bar{f} > \bar{m}$ is not needed to have $g_T'(Q_T) > 0$ in the last period of the game. Moreover, notice that $\bar{f} > \bar{m}$ is necessary to have a positive stock of public debt outstanding in the steady state (see Tabellini [1986]), and it is thus consistent with the nature of the problem addressed in this paper.

VI. THE OPTIMIZATION PROBLEM OF THE MONETARY AUTHORITIES AND THE CHARACTERIZATION OF EQUILIBRIUM

If the CB really is independent, its behavior is easy to describe; it will simply set $m_t = \bar{m}$ in every period. If, however, the CB is not independent (i.e., if $\tau = \bar{\tau} > 0$), then the dependence of f_t^* on Q_t gives the CB an incentive to preserve its reputation: the higher Q_t, the lower the size of fiscal deficits. Thus even a nonindependent CB could choose not to monetize current deficits, in order to exploit its reputation in later stages of the game. The conditions under which this will occur are set out in this section, for a time horizon of two periods.

In the last stage of the game, a nonindependent CB will always accommodate and play according to equation (6), since destroying its reputation can have no future adverse consequences. In the first period, however, the CB can accommodate and play (6), in which case it will destroy whatever reputation it had when the game started. Or it can refuse to accommodate, in order to build up or preserve its reputation and thereby induce the FA to reduce the pressure in the following period. By so doing it will bear the cost of not playing optimally in the current period, in exchange for some gains (in the form of lower deficits) in the future. Naturally, the choice between accommodation or no accommodation is taken so as to minimize expected loss.[7]

The history of the game up to period t is now summarized by two state variables, d_t and P_t, over both of which the CB indirect loss function is defined:

$$V_t^M(d_t, P_t) = \operatorname*{Min}_{m_t} \frac{1}{2}[(m_t - \bar{m})^2 + \bar{\tau} d_t^2] + \beta V_{t+1}^M(d_{t+1}, P_{t+1}). \tag{18}$$

If in period t the CB accommodates and sets $m_t \neq \bar{m}$, then, from (12.i), $P_{t+1} =$ 0 and (18) becomes

$$V_t^M(d_t, P_t) = \frac{1}{2}[(m_t^* - \bar{m})^2 + \bar{\tau} d_t^2] + \beta V_{t+1}^M(d_{t+1}^A, 0) \tag{19}$$

where m_t^* is the optimal accommodative monetary policy characterized in section III above. Vice versa, if in period t the CB refuses to accommodate and sets $m_t = \bar{m}$, then P_{t+1} is determined by (12.ii), and (18) becomes[8]

$$V_t^M(d_t, P_t) = \frac{1}{2}\bar{\tau} d_t^2 + \beta V_{t+1}^M(d_{t+1}^N, P_{t+1}). \tag{20}$$

Thus equation (19) indicates the CB indirect loss function if it accommodates

7. Given the learning process of the FA as summarized by (12), the CB will never find it optimal to "partially accommodate" (i.e., to behave "as if" its true parameter was $0 < \tau < \bar{\tau}$); equation (12) says that whenever $m_t \neq \bar{m}$ is observed, the FA will interpret that as an indication that the true τ is equal to $\bar{\tau}$. The question of how plausible is the learning process of the FA as postulated in (12) and of how eventually to improve on it is beyond the scope of this paper, but see Grossman and Perry [1985].

8. The variables d_{t+1}^A, d_{t+1}^N that appear in (19) and (20) are obtained from (14) and (13) respectively, with f_t being replaced by the optimal policy rule for the FA given in (17).

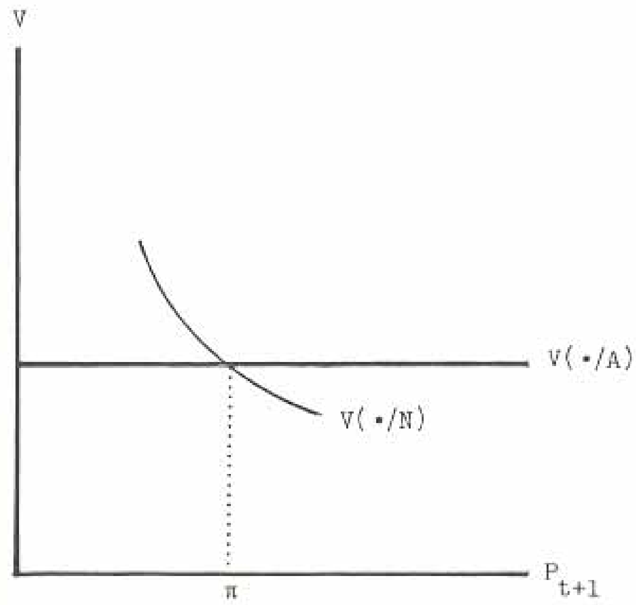

FIGURE 1

at time t; I will denote it simply by $V_t^M(P_t, d_t/A)$. And (20) indicates the CB indirect loss function if it does not accommodate at time t, which I will abbreviate as $V_t^M(P_t, d_t/N)$. The decision of whether or not to accommodate at time t will be taken by the CB by comparing $V_t^M(\cdot/A)$ and $V_t^M(\cdot/N)$.

This comparison can be illustrated by means of the diagram of Figure 1. In it, $V_t^M(\cdot/N)$ is drawn as the downward sloping curve, and $V_t^M(\cdot/A)$ as the horizontal line. An unpublished appendix available upon request proves that the two functions are continuous and that their qualitative properties are consistent with the diagram of Figure 1. At the point where $P_{t+1} = \pi$, the two functions intersect and the CB will be indifferent between accommodating or not. If $P_{t+1} > \pi$, the CB will be better off if it refuses to accommodate. Conversely, for $P_{t+1} < \pi$, the CB will prefer to monetize some of the debt.

The position of the two curves in Figure 1 depends, among other things, on P_t^*, the probability that a nonindependent CB will refuse to monetize the debt. When P_t^* changes, so does Q_t, the unconditional probability of no monetization; and any change in Q_t is reflected, through equation (17), in a change in f_t^*, and hence in a change in both $V_t^M(\cdot/N)$ and $V_t^M(\cdot/A)$. Thus π, the value of P_{t+1} which makes the CB indifferent between accommodating and not accommodating, is a function of P_t^*, defined implicitly by the equality between $V_t^M(\cdot/A)$ and $V_t^M(\cdot/N)$. It is possible to prove that $\pi(P_t^*)$ exists and is unique (note however that $\pi(P_t^*)$ need not lie between 0 and 1).

The equilibrium behavior of the CB and of the FA depends on the value actually taken by $\pi(P_t^*)$. Let $\underline{\pi}$ and $\bar{\pi}$ denote respectively the lowest and the highest values of $\pi(P_t^*)$, for $1 \geq P_t^* \geq 0$. In the Appendix it is proven that three types of equilibria exist, depending on the parameter values. All three of them are subgame perfect Bayesian equilibria (see Kreps and Wilson [1982]). In all three equilibria a nonindependent CB always accommodates in the last period of the game, and an independent CB never accommodates throughout the game. The three equilibria differ on the strength of the reputational incentives faced by a nonindependent CB in the first stage of the game.

The first equilibrium arises if $\bar{\pi} < P$ (where P summarizes the FA prior beliefs when the game is started) and is an instance of a pooling equilibrium. Here the reputational incentive is large enough so that even a nonindependent CB does not accommodate in the first stage of the game. Since the FA realizes it, it behaves as if the CB was absolutely independent, by setting $f_1^* = \bar{f} - g_1(1)$. The action of the CB here does not reveal any information, so that at the start of the second period, $P_2 = P$ and the FA sets $f_2^* = \bar{f} - g_2(P)$. This equilibrium is unique. Note that nothing constrains $\bar{\pi}$ to be nonnegative. Therefore, this equilibrium can arise even for arbitrarily small values of P—i.e., even for trivial amounts of uncertainty.

The second equilibrium arises if $\bar{\pi} > 1$, and is an instance of a separating equilibrium. Here the reputational incentives are never large enough, no matter how high is the prior probability P, and a nonindependent CB always accommodates. In the first period, however, the FA still ignores the nature of its opponent, so that it sets $f_1^* = \bar{f} - g_1(P)$. The action of the CB here is fully revealing. Thus, if the CB is nonindependent, then the FA will be able to set larger deficits for the remainder of the game: $f_2^* = \bar{f} - g_2(0)$. Conversely, if monetary policy in the first period is nonaccommodative, then the FA knows that it is facing an independent CB, and in the second period it will play $f_2^* = \bar{f} - g^2(1)$. Again, the equilibrium is unique.

The third equilibrium corresponds to the case $\bar{\pi}$, $\underline{\pi} \in [P,1]$. Here a nonindependent CB is just indifferent between accommodation and no accommodation, and it chooses a mixed strategy, consistent with the beliefs entertained by the FA. Since this third equilibrium is somewhat less interesting but at the same time more complicated than the other two, its detailed description is deferred to the Appendix.

VI. DISCUSSION AND CONCLUDING REMARKS

The following implications of the equilibrium analyzed in section VI are worth noting.

(1) In the pooling equilibrium and in the first stage of the game, a nonindependent CB chooses a less accommodative monetary policy than the one that it would have chosen in a world of complete information. Such a pooling equilibrium can exist even for infinitesimal amounts of uncertainty. Thus, as conjectured in the introduction, the monetary policy shift that occurred in Italy in 1981 can be explained as arising from the uncertainty about the future behavior of the Italian monetary authorities that was generated by the "divorce."

The model also predicts that the monetary policy shift should have been accompanied by a more moderate fiscal policy. The Italian evidence on this is difficult to interpret. The public sector borrowing requirement as a percentage of GDP had arrested its upward trend, and at the end of 1984 it was at approximately the same level of 15.5 percent as in 1982. However, such a level is still largely inconsistent with the objective of stabilizing the ratio of public debt to GDP. The interpretation of the Italian evidence is made even more difficult by the fact that the fiscal variable of interest is not really the public sector borrowing requirement, but rather the cyclically adjusted fiscal deficit net of interest payments. This variable is not readily available in the Italian published statistics. Rough estimates reported in Giavazzi [1984] suggest that this indicator of fiscal policy has fallen to below 3 percent of GDP in 1983, from a level of above 4 percent of GDP in 1982. Overall it seems fair to say that fiscal policy has indeed become more moderate in Italy since 1981, but to such a small extent that it does not yet provide a good confirmation of the predictions of the model.

(2) The uncertainty surrounding the extent of future debt monetization has changed the consequences of an accommodative monetary policy. Before the divorce, in the absence of any uncertainty, a monetization of public debt would have reduced the future stock of debt outstanding, by reducing the interest to be paid on the debt. After the divorce, an accommodative monetary policy, by destroying the reputation of the Bank of Italy, would cause larger fiscal deficits in the future, with ambiguous effects on the future stock of public debt in circulation. Going through some tedious algebra, it is possible to show that a nonaccommodative monetary policy can either raise or reduce the stock of public debt in the second period relative to a policy of debt monetization. It is more likely to reduce it the larger is $\bar{f}$ relative to $\bar{m}$, and the smaller is η. This ambiguity casts doubts on the common policy prescription that, in order to avoid crowding out of private capital accumulation, a CB faced with large fiscal deficits and a large stock of public debt should engage in debt monetization. For some parameter values, such a policy would not only sacrifice the CB monetary objectives, but it could even backfire and bring about a larger (and not a smaller) stock of public debt in circulation.

(3) At a more general level, the model analyzed in the previous sections has shown that when policy actions signal the policymaker's private information, their consequences can be drastically different than in a world of complete information. From the point of view of a positive theory of monetary policy, this implies that the selection of policy actions by the central bank is shaped by incentives that would be misunderstood if the signalling dimension were neglected. From the point of view of a normative theory of institutional reforms, it suggests that creating some uncertainty about the "virtues" of the monetary authorities can be a good substitute for the possibly more difficult task of creating a truly "virtuous" central bank, at least in the short run.

(4) The analysis carried out in the previous sections has maintained two hypotheses: that the time horizon lasts only two periods, and that the private

information is asymmetric in the sense that the CB is perfectly informed of the FA loss function.

There is no reason to suspect that the nature of the results would change if the first assumption were dropped, as long as the horizon remained finite. Since the formal analysis of the game involves dynamic programming methods, having more than two periods would amount to solving the recursions described in the paper for more than two periods. Even though the algebra would become increasingly complex, it is plausible to conjecture that the same three types of equilibria would still exist as described in section VI above. As the game evolves towards the end, reputational incentives presumably would become less and less strong, so that eventually a nonindependent CB would find it optimal to choose a mixed strategy or to accommodate right away. This pattern has indeed emerged in the literature on repeated static games (see Kreps and Wilson [1982], Barro [1986], Tabellini [1985b]), where a closed form solution could be more easily derived.

Dropping the second assumption, however, would seriously alter the results; if both players are imperfectly informed about the nature of their opponent, they would be playing a "game of chicken," as in Kreps and Wilson [1982]. Presumably, in the early stages of the game both authorities would refrain from adjusting their policies in the hope that the opponent would be the first to give in. While this occurs, the time path of public debt would exhibit an explosive trend. The basic model of this paper could be fruitfully extended to analyze this situation. Loewy [1986] has recently made some progress in this direction.

APPENDIX

Proof that the Perfect Bayesian Equilibrium is as Described in Section VI of the Text

(a) $\bar{\pi} < P$. If the CB plays $m_1 = \bar{m}$ with certainty (i.e., if $P_1^* = \text{prob}(m_1 = \bar{m}/\tau = \bar{\tau}) = 1$, from (12.ii) we have $P_2 = P$. By hypothesis, then, $P_2 > \bar{\pi}$, and the CB is indeed playing optimally (see Figure 1). From (10), $Q_1 = 1$; from (12.ii) and from the fact that $P_2^* = 0$ (since the game ends at $t = 2$), $Q_2 = P$. Inserting these values in (17), we obtain f_1^* and f_2^*. Since $\bar{\pi} = \text{Max}\ \pi(P_1^*)$, the condition $\pi(P_1^*) < P$ holds for all values of P_1^* and the equilibrium is unique.

(b) $\underline{\pi} > 1$. Since $P_2 < 1$ then $P_2 < \underline{\pi}$ and a nonindependent CB will always choose to accommodate in the first period (see Figure 1). Then $P_1^* = 0$ and from (10), $Q_1 = P$. If the CB does not accommodate, it reveals that it is independent: substituting $P_1^* = 0$ in (12.ii), we get $Q_2 = P_2 = 1$. If the CB does accommodate, from (12.i), $Q_2 = P_2 = 0$. When these values for Q_1 and Q_2 are inserted in (17), we obtain f_1^* and f_2^*. Since $\pi = \text{Min}_{1 \geq P_1 \geq 0}\ \pi(P_1^*)$, the condition $\pi(P_1^*) > 1$ holds for all values of P_1^*, and the equilibrium is unique.

(c) $\underline{\pi}, \bar{\pi} \in [P,1]$. Here the equilibrium is as follows. In the first period, the CB set $m_1 = \bar{m}$ with probability $P_1^* = (1 - \pi^*)P/\pi^*(1 - P)$ and accommodates

with probability $1 - P_1^*$; π^* is given by $\pi^* = \pi(P_1^*)$. The FA plays $f_1^* = \bar{f} - g_1(P/\pi^*)$. In the second period the CB accommodates, and the FA plays $f_2^* = \bar{f} - g_2(P_2)$ where $P_2 = 0$ if the CB has accommodated in the first period, and $P_2 = \pi^*$ otherwise. An independent CB never accommodates.

Proof. We must first show that $\pi^* = \pi(P_1^*)$ exists. By hypothesis, $\pi(P_1^*) \in (P,1)$ for $1 \geq P_1^* \geq 0$, and $\pi(P_1^*)$ is continuous. Let $P_1^* = (1 - P_2)P/(1 - P)P_2$, for $P_2 \in X \equiv (\underline{\pi},\bar{\pi}) \subset (P,1)$. Then, the function $h(P_2) \equiv \pi(1 - P_2)P/(1 - P)P_2$ maps X into itself and is continuous. By Brouwer fixed point theorem, a fixed point $\pi^* = \pi[(1 - \pi^*)P/(1 - P)\pi^*] \in X$ exists. Now, substituting the previous expression for P_1^* into (12.ii) yields

$$P_2 = P/[P + (1 - P)(1 - \pi^*)P/(1 - P)\pi^*] = \pi^*.$$

Hence, referring to Figure 1, the CB is just indifferent between playing $m_1 = \bar{m}$ or accommodating, and by choosing a randomized strategy it acts consistently with loss minimization. Substituting P_1^* into (10), we get $Q_1 = P/\pi^*$, which, substituted in the expressions for the optimal fiscal policy, equation (17), completes the proof.

Remark. In this third case, the equilibrium need not be unique; the mapping $h(\cdot)$ may have more than one fixed point. Uniqueness would hold if $h(\cdot)$ or $h^{-1}(\cdot)$ were contraction mappings, but this is very difficult to establish.

REFERENCES

Alesina, Alberto and Guido Tabellini. "Rules and Discretion with Non-Coordinated Monetary and Fiscal Policies." Center for Research in Economic Growth, Memorandum #267, Stanford University, 1985.

Backus, David and John Driffill. "Inflation and Reputation." *American Economic Review*, June 1985, 530–38.

Barro, Robert. "Reputation in a Model of Monetary Policy with Incomplete Information." *Journal of Monetary Economics*, January 1986, 3–20.

Basar, Tamer and Geert J. Olsder. *Dynamic Non-Cooperative Game Theory*. New York: Academic Press, 1982.

Blanchard, Olivier. "Debt, Deficit and Finite Horizons." *Journal of Political Economy*, April 1985, 223–47.

Cuckierman, Alex. "Central Bank Behavior and Credibility—Some Recent Developments." Photocopy, Tel-Aviv University, 1985.

Giavazzi, Francesco. "A Note on the Italian Public Debt." *Banca Nazionale del Lavoro Quarterly Review*, June 1984, 151–59.

Grossman, Sanford and Motty Perry. "Sequential Bargaining Under Asymmetric Information." Photocopy, Princeton University, 1985.

Kreps, David and Robert Wilson. "Reputation and Imperfect Information." *Journal of Economic Theory*, August 1982, 253–79.

Loewy, Michael. "Reaganomics and Reputation Revisited." Photocopy, George Washington University, 1986.

Lucas, Robert and Nancy Stokey. "Optimal Fiscal and Monetary Policy in an Economy Without Capital." *Journal of Monetary Economics*, July 1983, 55–93.

Persson, Mats, Torsten Persson, and Lars Svensson. "Time Consistency of Fiscal and Monetary Policies." *Econometrica*, forthcoming, 1987.

Pindyck, Robert. "The Cost of Conflicting Objectives in Policy Formulation." *Annals of Economic and Social Measurement* 5(2), 1976, 239–48.

Salvemini, Maria Teresa. "The Treasury and the Money Market: The New Responsibilities after the Divorce." *Review of the Economic Conditions in Italy*, February 1983, 33–55.

Tabellini, Guido. "Accommodative Monetary Policy and Central Bank Reputation." *Giornale degli Economisti e Annali di Economia*, July/August 1985a, 389–425.

———. "Centralized Wage Setting and Monetary Policy in a Reputational Equilibrium." UCLA Working Paper #369, 1985b.

———. "Money Debt and Deficits in a Dynamic Game." *Journal of Economic Dynamics and Control*, forthcoming, 1986.

Turnovsky, Steven and William Brock. "Time Consistency and Optimal Government Policies in Perfect Foresight Equilibrium." *Journal of Public Economics*, April 1980, 183–212.

Wilson, Robert. "Reputation in Games and Markets," in *Game Theoretic Models of Bargaining*, edited by Alvin Roth. London: Cambridge University Press, 1986.