Go and soothe the row.
Delegation of monetary policy under private information

by

Marcello D'Amato*
Barbara Pistoresi**

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* Department of Economics
University of Salerno
e-mail: damato@bridge.diima.unisa.it

** Department of Economics
University of Modena and Reggio Emilia
and European University Institute
e-mail: pistoresi@unimo.it

Go and soothe the row. Delegation of monetary policy under private information.*

Marcello D'Amato†
Department of Economics,
University of Salerno

Barbara Pistoresi
Department of Economics,
University of Modena and
European University Institute

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Abstract

In this paper we analyse a delegation game between the government and a completely independent central banker whose preferences are private information. We show that a bit of private information is sufficient to eliminate any incentive for the government to precommit monetary policy to an independent and conservative agent: both in a separating equilibrium and in a pooling equilibrium the central banker's optimal degree of conservativeness turns out to be the same as the government's one. J.E.L. E58,D82. Keywords: Monetary policy, Delegation, Signalling games

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†Corrisponding Author. Dipartimento di Economia, Università di Salerno, Via Ponte don Melillo, 84084, Fisciano, Salerno. Tel ++39 +89 963132, Fax ++39 +89 962339. Email damato@bridge.diima.unisa.it

"David Alexander Glencairn era, ritengo, un uomo molto temuto;
la sola notizia della sua venuta bastò a pacificare la città.
Ciò non impedì ch'egli decretasse alcune misure energiche"
Jorge L. Borges, L' Aleph, trad. it.p.143.

1 Introduction

The relationship between "society" and the agent in charge of monetary policy has been focused by recent literature as one of the main issues in the economic analysis of monetary policymaking, (see Persson and Tabellini, 1997, for a recent survey). The starting point has been a work by Kydland and Prescott (1977) who showed that, in a monetary policy game between a monetary authority and private agents the precommitment solution for the policymaker welfare dominates any discretionary solution. Rogoff (1985) interpreted their result as the possibility for a society prone to the temptation for inflation surprise to delegate monetary policy to an agent (central banker) who does not take into account the benefits that unexpected inflation may have on government's target variables (unemployment, service on outstanding nominal public debt). Rogoff (1985) also showed that, in a model with nominal rigidity and scope for stabilization policy, the optimal CB's preferences are not such that the agent in charge for monetary policy sets an infinite weight on the inflation rate, though his preferences penalize inflation more than the median voter does[1]. This is the celebrated Rogoff's result about the convenience for a Government to commit monetary policy to a completely independent and "conservative" CB though not an infinitely conservative one, by trading off a certain amount of flexibility in the policy response in exchange for a credibility gain.

>From the economic history point of view the credibility problem is relatively old issue. "In a pure commodity system, money looks after itself. [...] As banking and paper money developed in the nineteenth century govern-

[1]See Alesina and Grilli (1992) for an explicit reinterpretation of the Rogoff's model in terms of a political game where a population of citizens, differing only with respect to the relative weight which they assign to inflation and stabilisation, votes upon the preferences of the "governor" to appoint. For an alternative approach on the analysis of the relationship between "society" and the agent in charge of monetary policy see Walsh (1995) and Persson and Tabellini (1993). Persson and Tabellini (1997), pp. 37 ss. offer a critical analysis of the main differences and analogies between the precommitment and the contracting approach to the normative analysis of monetary policy making.

ments were forced to deal with the question of how to control the monetary system" (Blanchard and Fisher, 1987, pp.569-570). In a pure commodity system, the relationship between "the government" and trading agents is quite simple: it has just to establish the monetary standard in terms of the type of metal, symbols to be printed on the coins, units of accounts. In a paper money system a new task, and hence a new power, for the "government" arises: looking after the monetary system is no more a simple issue. In the absence of intrinsic value of the paper money, its conventional value must be purposively warranted: credibility becomes a problem. Public institutions (central banks) become responsible for this task, they are put in charge for the power to print money on the terms of a contract which is often implicit. Where does this power finds its institutional roots? In a democracy, it must be, in a very general sense and just as any other power, a delegated power. However, the nature of the delegation, in particular who (the constitution, the law, the government) is delegating what to whom, has not a sound theoretical foundation.

Following the interpretation by Alesina and Grilli (1992) we believe that the novelty of the Rogoff approach is the set up of a political as well economic framework that allows to ask and possibly to answer the following question: where does the power to print paper money comes from? What are the effects of possibly different insitutional arrangements on the actual working of the monetary system? If we are willing to agree on the idea that in a democracy this power is delegated by the government (median voter) to an independent agent, then it is shown that the power to print money is delegated not only for transaction costs (functional separation of powers) but also for an important strategic reason, to preserve the credibility of the value of a paper money.

The solution to the question asked above implicitly given by Rogoff can be rephrased as follows: provided that in a paper money system, the power to print money can (or, equivalently for the present discussion, is believed to) be used to reach targets different from the value of the money itself such as non distortionary public revenue source motive, stabilization motive, and provided that the monetary power is put in charge of the government (a majority of electors for simplicity), the government has incentive to delegate monetary policy to a different agent for strategic reason because of the credibility problem it has in the eyes of the private agents. The effect of the optimal commitment of monetary policy by the government to a conservative CB is that: a) credibility gains are traded off for a reduced stabilization, b) the variability in the preferences of the governments about the trade-off

between the value of the money and alternative targets is smoothed in the delegation process.

As stated above, the nature, the object and even the agents involved in the delegation process has not an agreed upon theoretical foundation. Other approaches to these issues have been put forward in the literature, after the seminal contributions reviewed above. On the normative side the contracting approach (Persson and Tabellini, 1993, Walsh, 1995) analyzes the relationship between the government and a CB and shows how each government, in the sequence of stage games defined by successive elections, can optimally arrange the relationship with the agent in charge of monetary policy such that the first best policy is delivered. The target approach, put forward by Svensson (1997), suggests that targeting inflation may be a better course of action to be assigned to an independent central banker. Both of these two approaches tend to take for granted that the institutional setting is such that the delegation contract occurs between the elected government (the principal as the ultimate source of the monetary power) and the CB (the agent). It is the ability of the clever design of the performance contract and the target setting that shelter monetary policy from politically motivated courses actions. By not addressing the issue of the institutional source of the monetary power, this approach, just like the Rogoff's approach "merely relocates the credibility problem" (McCallum, 1995).

On the positive side developments of the Rogoff approach elaborate on the nature of the political aspect of the game to find conditions under which it is convenient for the principal to relinquish monetary power in order to shield monetary policy from short run political temptations. In this approach delegation reduces the credibility problem, though the power to select the type of the agent in charge of monetary policy is maintained in the hands of the political system. For example, Alesina and Grilli (1992) modify the political set up in a very simple way such that the median voter, as a qualifier for the broad "society", is assumed to be the principal in the delegation process. This latter precommits its monetary power after election takes place. The implication is that by regarding the preference parameter as a random variable and the election process as its realisation, the Rogoff banker will achieve a double aim: will allow precommitment to governments after elections have taken place and, consequently, will stabilise the political variability in the society' preferences.

Alesina and Gatti (1995) directly address this point and further modify the political set up of the delegation process, and they show that the precom-

mitment may occurr before the election takes place. In their model, again, the benchmark case is an institutional setting where the government is given to the median voter (i.e. the government after an election) who is in charge of the power to delegate monetary policy as in Alesina and Grilli (1992). However they show that in the presence of a two party system the to two competing political parties will have incentive to delegate this power to an independent and conservative agent before the election takes place and the voters' preferences are revealed: if a precommitment solution is available, a two party system will use it. They also reinterpret the preference about the trade off between inflation stabilisation and alternative target as a specific source of variability in the model and show that delegation of monetary policy to a conservative CB will lead to a reduction in the inflation variability as well as a reduction in output variability. In the presence of a political source of output and inflation variability, the appointment of a conservative CB achieves a reduction in inflation fluctuations as well as a reduction in output variability.

An alternative solution to the credibility problem in monetary policymaking relies on the disciplinary effects that prolonged horizons and informational asimmetries between the policymaker and the public have on the behaviour of the agent in charge of monetary policy[2]. Backus and Driffil (1985) Barro (1986), Vickers (1986) consider the case when the policymaker is in office for more than one period and has private information on its preferences about the trade-off between alternative targets. In such situations the policymaker's behaviour in the first stages of his office conveys information about its preferences and affects public expectations in the subsequent periods. In this setting the clever scrutiny by the public will induce non myopic policymakers to discipline their temptation in the first period of the time horizon to collect future benefits. Broadly speaking, reputational equilibria are more effective and less costly to achieve the longer the time horizon of the agent trying to establish its own reputation. In those circumstances there may still be a case

[2]Different authors have emphasised that the environment in which the policymaker makes decisions is characterised by the presence of asymmetric information by the policymaker on its own preferences about alternative objectives to which policy is targeted. In the case of private information the action of the policymaker is constrained by private agents beliefs, but also has scope for policy actions that would be ineffective in the presence of complete information.The issue of private information in monetary policy games has been analysed, for example, by Backus and Driffil (1985), Canzonery (1985), Rogoff (1987), Vickers (1986).

for "society" to delegate monetary policy to an independent agent in office for a long horizon, longer than the office term of the government required by democratic institional settings. Rogoff (1985) himself emphasises this issue in his seminal contribution.[3].

Reputational models, however, are consistent with different institutional settings. Which one is prevailing has, in principle, different effects on the actual performance of monetary policy. If the arrangement is such that the elected government is given the final decision about the monetary policy, then reputational equilibria are a disciplinary device on the government's temptation and may contribute to shape the political business cycle. If the arrangement is such that an independent CB is given the final decision about monetary policy, reputation equilibria disciplines the CB's behaviour, sheltering monetary policy from politically motivated course of actions. There are however, good reasons to believe that the two alternative solutions, reputation and delegation to an independent agent, are not, in real world, separate issues: provided that the government is given the ultimate power about monetary policy, is it still the case that he is willing to delegate this power to an independent CB? How does the "subtle strategic aspects" involved in the relationship between between a privately informed CB and the public affect the choice of the government? It is certainly true that "in a multiperiod setting, reputational considerations will further help ameliorate the central bank's time consistency problems", what is less clear is if these circumstances will further help to ameliorate the *government's time consistency problem.*

[3]Rogoff (1985), p. 1177 introduces his conservative CB by stating "[...] society can make itself better off by selecting an agent to head the independent central bank *who is known* to place a greater weight on inflation stabilization (relative to unemployment stabilization), than is embodied in the social loss function [...]. The term of the agent last only one period, though in a multiperiod setting, reputational considerations will further help ameliorate the central bank's time consistency problems.", (Italic added). Moreover in his discussion he states, pp.1179-1180 "we have assumed that the preferences of the agent appointed to head the central bank can be known with certainty. Clearly many strategic problems arise when this assumption is relaxed. However, as long as there is some information on the probable preferences of alternative candidates, the basic point of the above analysis is still germane. The model is certainly consistent with the fact that central bankers are typically chosen from conservative elements of the financial community. One incentive that the head of the central bank might have for holding down inflation is that he can thereby improve his standing in the financial community, and thus earn greater remuneration upon returning to the private sectors". Taken at their face value Rogoff's comments about his result suggest that delegation is related to the reputational issues, information disclosure and the time horizon of the office in a fundamental way.

This is a particularly important issue to be established once we want to be confident that though in a democracy the ultimate source of the monetary power lies in the government's hands, provided that the proper nature of the credibility problem is recognised, the solution will be voluntary delegation to an independent agent.

The aim of this paper is to addres the questions above: if a precommitment solution is available but delegation of monetary policy occurs in the presence of private information of the policymaker on his preferences, is it still the case that the principal will use it? In the presence of private information of the agent on its own preferences the delegation involves additional costs and additional benefits which may affect the final decision made by the principal about the optimal degree of commitment.

In addressing this question, we accomplish our analysis in the simplest political setting by considering the timing of the model in Alesina and Grilli (1992), i.e., we assume that the insitutional setting gives the power to print money to a government whose preferences are dictated by the median voter aggregation process. Let us assume that private agents after election are still uncertain about the real identity of the median voter and of the independent agent delegated to monetary policy. Is it still the case that the government will appoint a conservative CB? The answer to this question will be shown to depend in a non trivial way on the informationally constrained behaviour of the players at different stages of the game. The model is easily summarised: at time $t = 0$ (delegation stage) a government is elected endowed with preferences over inflation and output stabilization, and delegates monetary policy to a CB in charge for two periods whose preferences are private information. At time $t = 1$ (stabilization stage) an output shock occurs; given agents expectations, the CB will set the inflation rate taking into account the fact that future expectations (at time $t = 2$) by private agents will be set conditional on the observation of the CB's current choice; macroeconomic outcomes are realised. At time $t = 2$ a shock hits the economy, the central banker will set its money supply, macroeconomic outcomes are realized and the game ends[4].

[4]This timing of the game is the same as in Vickers (1986) who shows that the subgame played by the CB at time 1 is a signalling game with both a separating and a pooling equilibrium strategies. He also shows that only the separating equilibrium survives the application of some refinement criteria. Differently from Vickers we analyse the signalling sub-game under the hypothesis of a continuum of types that the CB may incarnate. Then we solve for the optimal CB's type that the government may want to select under either equilibrium.

Both in a separating and in a pooling equilibrium a given type of government have to afford costs and may obtain benefits from the presence of private information of the public about its preferences. Broadly speaking, in a separating equilibrium a tough type will afford costs in the first period in order to credibly signal its own preferences to private agents and will collect benefits in the second period when private agents' expectations are set according to its actual type. A wet type will collect benefit from private information since in a separating equilibrium, private agents will reduce expectations about inflation. In a pooling equilibrium a tough type will be worse off in both periods depending on private agents expectations. A wet type may improve its welfare because it will benefit from surprise inflation in the second period. We will consider both pooling and separating equilibrium and show how, in either case, the incentive to exploit the CB's degree of conservativeness as a commitment device is modified by the presence of private information.

The remaining of the paper is organized as follows: in section 2 we outline the model and define the separating equilibrium and the pooling equilibrium in the monetary policy sub-game; in section 3 we derive the optimal CB's degree of conservativeness set by the government in the delegation stage; in section 4 we conclude.

2 The economic environment, the payoff functions of the players and the timing of the game

The timing of the game is as follows: in the first stage of the game ($t = 0$) a Government is elected and is characterised by the same preferences about alternative targets as the median voter in the "society". It has to decide whether to appoint an independent central banker in charge fo two periods, whose preferences about the trade off between costs of inflation and the benefits from stabilization are private information from the public's point of view. In each of the two periods ($t = 1$, $t = 2$), the central banker plays a stabilization game vis à vis the private agents. This stabilisation (sub)game has the usual sequence: private agents formulate inflation expectations, given their information set and set nominal contracts conditional on these expectations, an output shock ε_t, $t = 1, 2$, hits the economy. In each period the state of

the economy is given by the usual expectations augmentd Phillips curve

$$x_t = \pi_t - \pi_t^e + \varepsilon_t \tag{1}$$

where the output to inflation elasticity has been normalised to one and the natural output growth rate to zero. The output shock is assumed to be an i.i.d random process such that $\varepsilon_t \in [\underline{\varepsilon}, \overline{\varepsilon}]$, whose distribution function is given by $G(\varepsilon)$ and is such that: $E(\epsilon) = 0$, $E(\epsilon^2) = \sigma^2$, $E(\epsilon_1 \varepsilon_2) = 0$ the state of the economy defined by the random shock is assumed to be common knowledge among the players. The per period pay off function assigned to the central banker is given by

$$W_t = -\frac{1}{2}\pi_t^2 - \frac{\alpha}{2}(x - \overline{x})^2 \tag{2}$$

where the target inflation rate has been normalised to zero, the output target $\overline{x} > 0$ is above the natural rate given to labour market and fiscal distortions and α represents the preferences parameter that describes CB's relative weight to alternative targets. This parameter is private information for the central banker and from the point of view of the private agents is distributed according to a prior beliefs distribution function $F(\alpha)$ defined over the compact support $\alpha \in [a, A]$ [5].

Private agents, in formulating their expectations, conditional on their information set will minimize the forecast error according to the following per period payoff function

$$u_t = -(\pi_t - \pi_t^e)^2 \tag{3}$$

The Government payoff function is given by

$$W_t^g = -\frac{1}{2}\pi_t^2 - \frac{\alpha_g}{2}(x - \overline{x})^2 \tag{4}$$

We also assume, for the sake of simplicty and without affecting the results in a significant way that the players do not discount future so that the payoff function on the time horizon of the game are the following ones: $W = W_1 + W_2$ for the CB and $W^g = W_1^g + W_2^g$.

[5] Both the support and the distribution function are common knowledge among the players and may be arbitrarily defined. However, it can be shown that conditions for the existence of a separating equilibrium under the hypothesis of a continuum of types may restrict the support. Cfr. Mailath (1987).

The game is solved by backward induction, i.e. we first solve the two periods stabilisation game and than, given the continuation game we solve for the Government's optimal degree of commitment at time $t = 0$. The solution concept we adopt for the stabilization game is the Bayes- Nash concept: this is a quite standard signalling game with a continuity of types, whose equilibria have been characterised by Mailath (1987). By solving the game we obtain a couple of inflation rates played by the central banker: $s = [\pi_1(\alpha; \varepsilon_1),\ \pi_2(\alpha; \varepsilon_2)]$, and a couple of expected inflation rates played by private agents: $e = [\pi_1^e(\alpha^e), \pi_2^e(\pi_1; \varepsilon_1)]$, where: $\pi_1^e(\alpha^e) = E[\pi_1(\alpha; \varepsilon_1)]$ represents the first period expected inflation conditional on prior beliefs and $\pi_2^e(\pi_1; \varepsilon_1) = E[\pi_2 \mid \pi_1(\alpha; \varepsilon_1)]$ represents the second period expected inflation rate observed in the first period conditional on the inflation rate observed in the first period, and set according to the Bayes rule.

Before moving to the solution of the game let us notice that the timing and the informational assumptions adopted in the present formulation of the model does not allow for electoral uncertainty as, for example, in Alesina and Gatti (1995), since private agents first period expectations are set after the election[6]. Instead our formulation allows us to consider a form of political uncertainty arising after the election of the game. Two different interpretations of the results derived below arise in according to the assumptions about the government's type, either if it is commmon knowledge or not among the players. In either case the main point of the paper is not affected. Assume, for example, that in a two party system a conservative government is elected, this refines the information set on which the public may condition their expectatios before setting contracts. However it may still be the case, and there are, we believe, plenty of historical episodes in which this was indeed the case, that the public is still uncertain about how much the elected party is really commited to its electoral platform. We think our model to be useful to interpret this situation. Alternatively it may be the case that elections solve the informational problem in such a way that the public perfectly knows the type of government he is facing. In this latter case our timing structure is still useful to answer the following question: is it still the case that the government is willing to appoint a Rogoff conservative CB? More details on this point will be given in the following.

[6]In a companion paper we show that the results derived in the present paper only partially carry over to the case of electoral uncertainty, i.e. when first period expectations are set before the election outcome.

3 Equilibria in the monetary policy game

As stated above the two period stabilization game played by the CB is a quite standard signalling game, (see Vickers,1986). However, differently from standard signalling game the uninformed agent (the public) is called to formulate expectations on random variables of different nature: the private information random variable (α) and the stochastic ooutput shock (ε_t), this structure mildly affect the conditions under which equiilbrium strategies can be derived. Moreover, as a signalling game it admits for different types of equilibria: separating equilibria and pooling equilibria. We will study both of them and will then derive the optimal degree of commitment of a government to a central banker with suitable preferences[7].

3.1 The Separating Equilibrium for the Stabilization Game

In the first period under a separating equilibrium different CB types will select different strategies conditional on the state of the economy (ε_1). The argument is the usual one: in order to credibly convey information to the public the first period choice the CB's choice in the first period in office is constrained by the incentive compatibility condition, to prove that they are really tough, CB characterised by a low degree of temptation for output stabilisation have to choose inflation rates which less tough types would not be willing to imitate in equilibrium. The CB's optimal type contingent strategy can be computed by backward induction: the public expections on the second period inflation rate will be set conditional on the observation of the inflation rate played in period 1. At time $t = 1$ the CB will anticipate this and, given the realisation of ε_1 will choose an incentive compatible inflation rate to achieve a) output stabilization and b) a credible information release about its preferences about inflation.

The equilibrium value for the second period inflation rate can be easily computed by solving the folloing program:

[7]Many refinement criteria are now available in the literature. Unfortunately all of them refer to the case of finite number of types that the informed party ma incarnate. (See Mailath, 1987, 1992). Again, in the present setting it will be shown that the type of equilibrium strategies followed by the central banker does not affect the government's optimal degree of commitment.

$$\begin{aligned} \underset{\pi_2}{Max}\ W_2 = \quad & -\tfrac{1}{2}\pi_2^2 - \tfrac{\alpha}{2}(x_2 - \overline{x})^2 \\ s.t. \quad & x_2 = \pi_2 - \pi_2^e + \varepsilon_2 \\ & \pi_2^e = E[\pi_2 \mid \pi_1] \end{aligned}$$

which yields the following first order condition

$$-\pi_2 - \alpha(\pi_2 - \pi_2^e + \varepsilon_2 - \overline{x}) = 0 \tag{5}$$

Private agents expectations, given their information set, can be obtained by computing the expected value of (5) over ε_2 and α conditional on π_1 which yelds

$$\pi_2^e = \widehat{\alpha}\overline{x} \tag{6}$$

where $\widehat{\alpha} = E(\alpha \mid \pi_1) = \phi^{-1}(\pi_1)$, as dictated by the Bayes rule, where ϕ represents the separating strategy in the first period of the game and is a one to one mapping from the type space onto the strategy space (see Mailath, 1987).

By substituting back 6 into 5 we get

$$\pi_2 = \frac{\alpha(1+\widehat{\alpha})}{1+\alpha}\overline{x} - \frac{\alpha}{1+\alpha}\varepsilon_2 \tag{7}$$

The two terms of (7) represent the usual inflationary bias and the stabilisation component. Notice that the inflationary bias which afflicts the second period monetary policy environment depends on the choice the CB has made in the first period, through the beliefs updating. Notice that the predictable component of inflation in (7) is apparently different from the predicted component in (6), however in a separating equilibrium $\alpha = \widehat{\alpha}$ and expectations in (6), given (7), are indeed rational they are evaluated at equilibrium.

The equilibrium output process can be obtained by substituting (7) into (1) and will be given by

$$x_2 = \frac{\alpha - \widehat{\alpha}}{1+\alpha}\overline{x} - \frac{1}{1+\alpha}\varepsilon_2 \tag{8}$$

Notice that the output process can be decomposed into to componements: the first term represents the inflation surprise component and the second the stabilisation component.

Let us move now to the first stage of the game: given a separating equilibrium, the CB will satisfy:

$$\underset{\pi_1 \in \phi}{Arg\max}\ \widetilde{W} = \int_{\varepsilon_2} -\frac{1}{2}\pi_1^2 - \frac{\alpha}{2}(\pi_1 - \pi_1^e + \varepsilon_1 - \overline{x})^2 - \frac{1}{2}[\frac{\alpha(1+\widehat{\alpha})}{1+\alpha}\overline{x} - \frac{\alpha}{1+\alpha}\varepsilon_2]^2 - \frac{\alpha}{2}[-\frac{1+\widehat{\alpha}}{1+\alpha}\overline{x} + \frac{1}{1+\alpha}\varepsilon_2]^2 h(\varepsilon_2)d\varepsilon_2 \tag{9}$$

By using the definition of a separating equilibrium strategy, $\pi_1 = \phi(\alpha)$, and the Bayes rule $\widehat{\alpha} = \phi^{-1}(\pi_1)$ we obtain the first order condition for the CB, i.e., which, evaluated at equilibrium $\widehat{\alpha} = \alpha$, yields the following differential equation whose solution has to be satisfied in a separating equilibrium:

$$\phi' = \frac{\alpha\overline{x}^2}{\alpha[\overline{x} + E(\phi) - \alpha\varepsilon_1] - (1+\alpha)\phi} \tag{10}$$

where $E(\phi)$ is the expected first period inflation rate in a separating equilibrium computed according to the prior beliefs.

Notice that the separating strategies depends on the actual type appointed as the head of the central bank, but also on the output target, on the prior expectations of the agents and on the state of the economy in the signalling period. (10) can be characterised qualitatively by using characterisation theorems in Mailath (1987) and can also be solved analytically (see Appendix).

In order for (10) to be an equilibrium separating strategy and to qualitatively characterise it, we study monotonicity conditions on the reduced form payoff function of the informed party in the signalling game as defined in Mailath (1987). Those conditions are: (1) a *belief monotonicity condition* given by $\partial\widetilde{W}/\partial\widehat{\alpha} = -\alpha(1+\widehat{\alpha})/(1+\alpha)\overline{x} < 0$, intuitively, the CB would prefer to be believed to be a tough type in fighting inflation because this reduces the inflationary bias and, coeteris paribus, makes surprise inflation a more effective course of action; (2) a *type monotonicity condition* given by $\partial^2\widetilde{W}/\partial\pi_1\partial\alpha = -(x-\overline{x}) > 0$, for $x < \overline{x}$, under this condition the marginal benefit of increasing inflation is increasing in α[8]; (3) a *single crossing condition* given by $\partial[\widetilde{W}_{\pi_1}/\widetilde{W}_{\widehat{\alpha}}]/\partial\alpha = -(x-\overline{x})/\alpha(1+\widehat{\alpha})\overline{x} > 0$ for $x < \overline{x}$, under this

[8]The condition we impose may not hold for particularly high and positive realization in the output shock. Contingent on this occurence the complete information inflation rate $\pi_1(\alpha)$ will not be monotonically increasing in α given an arbitrary support $[a, A]$. Consequently the signalling schedule $\phi(\alpha)$ will change slope and will exhibit a discontinuity, in this arbitrary support, see Mailath (1987), Theorem 1 for a characterization of such

condition the marginal rate of substitution between an increase in inflation at time $t = 1$ and a reduced reputation tomorrow (an increse in $\widehat{\alpha}$) is increasing in α, intuitively, the weaker the banker, for a given realization of the shock, the more he is willing to pay in terms of future reputation for a unit increase of inflation today. Finally, an initial condition for (10) is required for the complete characterization of the separating strategy: following condition (6) in Mailath (1987), p.1352, since $\widetilde{W}_{\widehat{\alpha}} < 0$ we set $\phi(A) = \pi_1(A) = A\overline{x} - \frac{A}{1+A}\varepsilon_1$, i.e. in a separating equilibrium, the weakest possible type of banker will set the inflation rate that would have been chosen under complete information. Under these conditions a separating equilibrium exists and is described by (10). These results are summarised in the following

Lemma 1 *For any distribution function of prior beliefs $F(\alpha)$ defined on the compact support $[a, A]$, a separating equilibrium strategy exists. The solution to the stabilization game is given by the following equilibrium strategies $s^s = [\pi_1^s(\alpha;\varepsilon_1), \pi_2^s(\alpha;\varepsilon_2)]$, $e^s = [\pi_1^e(\alpha^e), \pi_2^e(\pi_1;\varepsilon_1)]$, where $\pi_1^s(\alpha;\varepsilon_1) = \phi(\alpha)$, π_2^s is given by (7) evaluated at $\widehat{\alpha} = \alpha$, $\pi_1^e = E[\phi(\alpha)]$, $\pi_2^e = \alpha\overline{x}$. The separating strategy satisfies (10), is monotonically increasing and continuous for $x < \overline{x}$.*

Proof. Apply Theorem 3 in Mailath (1987), p.1353 to (9) and get the result.

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discontinuities . We think however that by concentrating on the support of ε such that $x < \overline{x}$, we eliminate uninteresting, and possibly counterintuitive economic situations implicit in the quadratic specification of the CB's pay-off function: contingent on a large positive output shock it may be easily shown, by simple simulations on the equilibrium inflation strategy, that there exist a range in an arbitrary support $[0, A]$ where the inflation rate is decreasing in α. Intuitively this means that the higher the weight assigned by the CB to output stabilisation, the lower the equilibrium inflation rate. Moreover in this range the equilibrium inflation rate under complete information will turn out to be negative. Our assumption implies that we concentrate on positive inflation rate.

This assumption may be stated alternatively in the following way: the marginal benefit from surprise inflation, contingent on the shock realization, is given by $\partial W(.)/\partial\pi_1 = -\pi_1 - \alpha(x - \overline{x})$. The marginal benefit from inflation is increasing in α if and only if $x - \overline{x} < 0$. Our interpretation of CB's degree of conservativeness is that the higher the marginal benefit from inflation, given an output shock realisation, the lower the degreee of conservativeness.

Finally, it is worth noticing that by suitable restrictions of the support for the prior beliefs distribution, monotonicity assumptions considered above can be shown to hold even in the case when $x - \overline{x} > 0$. In that case the solution to the CB program will still satisfy (10) and the results to be derived about the optimal degree of commitment of the government will not change.

Corollary 1 *If $x < \overline{x}$ the inflation rate played in the first period in a separating equilibrium will be less than the equilibrium inflation rate played under complete information, for any realization of the shock and for any $\alpha \in [a, A)$ except for $\alpha = A$.*

Proof. *Given that $\widetilde{W}_{\widehat{\alpha}} < 0$, the intial value condition for (10) is such that $\phi(A) = \pi_1(A) = A\overline{x} - \frac{A}{1+A}\varepsilon_1$, where $\pi_1(A)$ is the complete information inflation rate for type A CB. Moreover for $\alpha \to A$, $\phi' \to \infty$. Then by Lemma 1, since for $x < \overline{x}$, ϕ is monotonically increasing, $\phi(\alpha) < \pi_1(\alpha)$, for $\alpha < A$.* ■

3.2 A Pooling Equilibrium for the Stabilization Game

In a pooling equilibrium the first period strategy chosen by different types of CBs do not allow private agents to learn anything about which kind of CB they are really facing. In this case, by definition the optimal strategy will be a constant function from the type space to the strategy space. As usual there are many possible pure strategies pooling equilibria, we concentrate our analysis on the pooling strategy delivering the optimal precommitment policy rule and validating the prior expectations of the public $E(\alpha) = \overline{\alpha}$, defined as the unconditional mean from the prior beliefs distribution function. The equilibrium value for the second period inflation rate can be easily computed by solving the following program:

$$\begin{aligned} \underset{\pi_2}{Max}\ W_2 = \quad & -\tfrac{1}{2}\pi_2^2 - \tfrac{\alpha}{2}(x_2 - \overline{x})^2 \\ s.t. \quad & x_2 = \pi_2 - \pi_2^e + \varepsilon_2 \\ & \pi_2^e = E[\pi_2] \end{aligned} \tag{11}$$

which yields the following first order condition

$$-\pi_2 - \alpha(\pi_2 - \pi_2^e + \varepsilon_2 - \overline{x}) = 0 \tag{12}$$

The private agents' expectation, given their information set can be obtained by computing the unconditional expected value of the equation above and it is given by

$$\pi_2^e = \overline{\alpha x} \tag{13}$$

where $\bar{\alpha} = E(\alpha)$,

By substituting back (13) into (12) we get

$$\pi_2^p = \frac{\alpha(1+\overline{\alpha})}{1+\alpha}\overline{x} - \frac{\alpha}{1+\alpha}\varepsilon_2 \tag{14}$$

As in the separating equilibrium, the two terms of (14) represent the usual inflationary bias and the stabilization component. By substituting (14) and (13) into (1) we get the second period output process defined by

$$x_2^p = \frac{\alpha - \overline{\alpha}}{1+\alpha}\overline{x} + \frac{1}{1+\alpha}\varepsilon_2 \tag{15}$$

Let us move now to the first period of the game: many possible pooling equilibrium strategies exist, we concentrate on the optimal contingent monetary rule validating prior beliefs defined as:

$$\pi_1^p = -\frac{\overline{\alpha}}{1+\overline{\alpha}}\varepsilon_1 \tag{16}$$

$$x_1^p = \frac{1}{1+\overline{\alpha}}\varepsilon_1 \tag{17}$$

In order to be an equilibrium these strategies must be supported by out of equilibrium beliefs such that deviation from the candidate strategy (16) is not worthwhile. Out of equilibrium beliefs must be such that there is no incentive, for any of the CB's type in the support, and given the realization of the output shock in the first period, to deviate from the optimal contingent rule, given the expectations of the agents. This is one of the point where the presence of a stochastic shocks affect the conditions under which standard pooling strategies can be computed. Consider for example an arbitrary support for the output shock. If a particularly bad shock occurs there will always exist types willing to deviate from the candidate pooling strategy in order to stabilize the economy. As a consequence of this, some restrictions on the support of the output shock is required in order to find out of equilibium beliefs that support the candidate pooling strategy. However this is not really relevant for the point made in this paper: assume, for the moment, that this condition holds (further details on the incentive to deviate and on out of equilibrium beliefs supporting the candidate strategies are provided in the appendix) and that there exist out of equilibrium beliefs such that any type of CB is not willing to deviate from the candidate pooling strategy implementing the optimal stabilisation rule in the first period. The discussion above can be summarised in the following

Lemma 2 *For any distribution function of prior beliefs $F(\alpha)$ defined on the compact support $[a, A]$, a pooling equilibrium strategy given by (16) may exist for some out of equilibrium beliefs that the private agent may hold after deviation. The solution to the stabilization game can be described by the following equilibrium strategies: $s^p = [\pi_1^p(\alpha;\varepsilon_1), \pi_2^p(\alpha;\varepsilon_2)]$, $e^p = [\pi_1^e(\alpha^e), \pi_2^e(\pi_1;\varepsilon_1)]$, where $\pi_1^p(\overline{\alpha};\varepsilon_1) = -[\overline{\alpha}/(1+\overline{\alpha})]\varepsilon_1$, π_2^s is given by (14), $\pi_1^e = 0$, $\pi_2^e = \bar{\alpha}\overline{x}$.*
Proof. *See Appendix.* ■

4 The optimal degree of commitment in the presence of private information of the CB on its preferences

Having characterised the possible equilibrium behaviour of the appointed agent in the presence of private information on its preferences let us move now to the analysis of the optimal precommiment action that the government takes at the start of the game (delegation stage). As stated in the introduction we can solve the game under different assumptions about the information that the public has about the government type. We will consider both a) the case when the government has private information on its real preferences about the trade off between inflation and stabilisation and b) the case when the public knows the preferences of the government.

Consider first case a), a government is elected, either a conservative type $\alpha_g = \alpha_c$ or a democrat type $\alpha_g = \alpha_d$, but the public cannot say how tight is its commitment to preferences declared into its electoral platform, what is known by the public is that $\alpha_c \in [\underline{\alpha}_c, \overline{\alpha}_c]$ and $\alpha_d \in [\underline{\alpha}_d, \overline{\alpha}_d]$, and are distributed respectively according $F(\alpha_c)$ and $F(\alpha_d)$ with $E(\alpha_c) < E(\alpha_d)$ (non overlapping supports is not a necessary conditionfor the argument below). After elections and before contract are set, the government appoints an independent agent with preferences into an arbitrary support $\alpha \in [a_i, A_i]$ which may be different for the two governments, i.e., $i = c, d$. If we assume that the type appointed is not observed by private agents then the sequential game after election is the same as the one analysed in the previous sections. In choosing its banker, each rational government realises that the subsequent stabilisation game will be played under the informational constraints described in the previous sections. We can then characterise the government's choice in any of the possible equilibria in the signalling game by using Lemma

1 and Lemma 2 by a suitable redefinition of the inital support for the prior beliefs distribution function.

Consider case b), a government is elected and its preferences are common knowledge to the public. As in case a) he may want to consider the possibility to appoint an independent agent whose preferences are private information and will select an independent agent $\alpha \in [a_i, A_i]$, possibly a conservative one, $\alpha \leq \alpha_g$. The only difference is now that the public will use its information about the government's preferences to set first period expected inflation, given the optimal choice of the government.

Before solving the government's problem consider first the optimal policy under complete information of the public about the CB's preferences as a banchmark. This is the standard Rogoff problem, the only difference being given by the fact that the banker is in charge for two period. The two periods are, however identical, no discounting has been assumed and hence the optimal degree of commitment will be the same as derived in Rogoff (1985).

To make its delegation choice the government will solve the following problem:

$$\begin{aligned} \underset{\alpha}{Max}\ W_g(\alpha) = \ & \int_{\varepsilon_1}\int_{\varepsilon_2}[-\tfrac{1}{2}\pi_1^2 - \tfrac{\alpha_g}{2}(x_1-\overline{x})^2 \\ & -\tfrac{1}{2}\pi_2^2 - \tfrac{\alpha_g}{2}(x_2-\overline{x})^2]h(\varepsilon_1)h(\varepsilon_2)d\varepsilon_1 d\varepsilon_2 \end{aligned} \tag{18}$$

where α_g represents the government's preference parameter about alternative targets, α the preferences parameter of the agent in charge of monetary policy for the next two periods. $W_g(\alpha)$ will take a different form depending on the equilibrium strategy in the signaling game in the stabilization game.

Given a separating equilibrium, the first period CB's strategy will be given by the separating strategy (10), the second period will be played under complete information of the public about the CB's preferences and the inflation rate will be given by (7) evaluated at equilibrium $\widehat{\alpha} = \alpha$. The reduced form of the government's payoff function given a separating equilibrium will be

$$\begin{aligned} W_g^s(\alpha) = \ & \int_{\varepsilon_1}\int_{\varepsilon_2}\{-\tfrac{1}{2}\phi(\alpha)^2 - \tfrac{\alpha_g}{2}[\phi(\alpha) - E(\phi) + \varepsilon_1 - \overline{x}]^2 \\ & -\tfrac{1}{2}(\alpha\overline{x} - \tfrac{\alpha}{1+\alpha}\varepsilon_2)^2 - \tfrac{\alpha_g}{2}(-\overline{x} + \tfrac{1}{1+\alpha}\varepsilon_2)^2\}h(\varepsilon_1)h(\varepsilon_2)d\varepsilon_1 d\varepsilon_2 \end{aligned} \tag{19}$$

Given a pooling equilibrium, the first period strategy will be given by the optimal stabilization rule validating the prior beliefs as described by (16), in

the second period the pooling strategy will be given by (14). The reduced form of the government's payoff function, given a pooling equilibrium will be given by

$$W_g^p(\alpha) = \int_{\varepsilon_1}\int_{\varepsilon_2}\{-\tfrac{1}{2}(\tfrac{\bar{\alpha}}{1+\bar{\alpha}}\varepsilon_1)^2 - \tfrac{\alpha_g}{2}[\tfrac{1}{1+\bar{\alpha}}\varepsilon_1]^2 - \tfrac{1}{2}[\tfrac{\alpha(1+\bar{\alpha})}{1+\alpha}\overline{x} - \tfrac{\alpha}{1+\alpha}\varepsilon_1]^2 - \tfrac{\alpha_g}{2}[\tfrac{(1+\bar{\alpha})}{1+\alpha}\overline{x} + \tfrac{1}{1+\alpha}\varepsilon_2]^2\} f(\varepsilon_1)f(\varepsilon_2)d\varepsilon_1 d\varepsilon_2 \tag{20}$$

The optimal CB's degree of conservativeness can be obtained by maximizing (19) and (20) with respect to α and the following proposition is obtained:

Proposition 1 *In any perfect equilibrium of the delegation game, given either (i) a separating equilibrium or (ii) a pooling equilibrium in the subsequent stabilization stages played between the CB and the public, the optimal degree of conservativeness is the same as the government's one, i.e.* $\alpha = \alpha_g$.

Proof. See Appendix ■

Under case a) the implication of proposition 1 will be that the incentive to precommit monetary policy will be completely destroied by the costs and the benefits that the government has to afford, and is willing to exploit in the case when the CB's type is private information. The same occurs under case b) with the difference now that after election the public will be completely informed about the preferences of the government. This means that the public can solve the same problem and conditional on the same information set as the government. Therefore it will realise the incentive for the governments to appoint a CB with the same prferences as the government's ones and will set first period expectations accordingly. This second interpretation of the game may seem to be quit paradoxical, but it is perfectly consistent with the information asymmetries that the appointment of a banker with not a well established reputation will determine. If there is a precommitment available to the government, but this precommitment technology is not common knowledge, then the government will be not willing to use it.

Let us discuss now the reasons why, under private information of the CB about its preferences the incentive to appoint an independent "conservative" banker disappears. Consider first a separating equilibrium. In such an equilibrium, the appointment of a conservative banker $\alpha < \alpha^g$ will require delegation costs in the first period and benefits in the second period.

The first period costs is due to the fact that a conservative CB will set a lower inflation rate to establish its reputation (to satisfy incentive compatibility conditions). When the government's type is not commone knowledge (case a) this will prevent a weak government to exploit the reduction that a saparating equilibrium induces in the expected level of inflation and will inflict to a strong government separating costs since deflationary distortions by a conservative banker are by definition larger than the deflationary distortios induced by a non conservative CB ($\alpha < \alpha^g$). When the government type is common knowledge (b) the welfare costs are due to the the deflationary distortion in the first period due to the incentive compatibility condition. In the second period the government will collect benefits in the form of an expected reduction in the inflationary bias. For the selected specification of the welfare function first period costs will exactly counterbsalance second period benefits. This explains point (i) in proposition1.

In any pooling equilibrium, on the other hand, the first period inflation rate is completely constrained by the private agents prior beliefs and the choice of the banker's type is actually irrelavant for costs and benefits in the first period, a rational governement will thensimply trade off costs and benefits in the second period of the banker's office. But in a pooling equilibrium, the expected inflation level is exogenously given by prior expectations, i.e. by definition the public does not updates its beliefs aount CB's type after a pooling equilibrium strategy. Then, a weak type will not waste the opportunity to artificially booming the economy according its own preference parameter and hence will never be willing to appoint a conservative CB. This holds true if the government type is private information (case a).

In case (b), on the other hand, the informationally constrained behaviour of a CB with private information about its type will induce in any case the only rational expectations that the public may have about the CB's type is the same as the government one and hence the stabilization game will be played according to the standard complete information strategies (inflationary equilibrium).

5 Conclusions and final comments

In this paper we have shown that when the government appoints a CB for two periods and his preferences are private information, the optimal degree of conservativeness is th same as the government one both in a separating

equilbrium. The intuition for the result is that the introduction of private information on CB's preferences increases the costs for government's commitment up to the level that, in the optimum, even if available, it will not be used by the government to constrain its future behaviour.

There are some implications of our results for the institutional design of monetary policymaking and the debate on conservative CB as a precommitment device. First of all, on the positive side, our results are in line with the work by Posen (1995,1998) who has repeatedly stressed that the interpretation of the inverse relationship between independence (conservativeness) and actual inflation is not causal and can be simply read the other way round: there are not conservative CB delegated by clever governments that keep inflation under control, when the "society" does not care about it. The implication of our analysis may represent a justification for Posen's claim: we should observe lower and more stable inflation rates in the "society" who cares about inflation. A second implication of our model, on the normative side, is related to the "relocation problem" put forward by McCallum (1995) is even more severe than in his argument. Referring to the contract approach (but the same is true for the simple delegation Rogoff's scheme) McCallum states: "if the absence of any precommitment technology is actually a problem, then it must apply to the consolidated central bank- government entity [...]. If the technology does not exist, then it does not exist". The implication of our model is that even if the techonology exists, when it is accompanied by informational constraints and costs, then it may not be used. Our results however reinforce his conclusions according to the benefits from central-bank independence and (conservativeness) have to be related to the insulation of monetary policy from the pressures of day to day politcal activity in democratic nations. The implications of private information for a model along the lines set in Alesina and Gatti (1995) is left for future work.

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