Central Bank Reputation

and Conservativeness

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DISCUSSION PAPER 216

September 1995

FINANCIAL MARKETS GROUP

AN ESRC RESEARCH CENTRE

LONDON SCHOOL OF ECONOMICS

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

ISSN 0956-8549-216

CENTRAL BANK REPUTATION AND CONSERVATIVENESS

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Revised June, 1995

Abstract

In a monetary game played by the private sector and a central bank (CB), who has private information, reputation may not completely solve the CB time inconsistency problem. An alternative solution is CB conservativeness. The optimal degree of CB conservativeness is solved in both the reputational and non-reputational regime and reputation is proved to be a substitute for conservativeness. Unless reputation works perfectly, the public can always gain from a conservative CB. Our model offers a unified framework to analyze both CB reputation and conservativeness. Our result can explain why low-reputation CBs find it worthwhile to peg the exchange rate to the currency of a high-reputation CB and why a highly reputable CB, like the Bundesbank, can afford to miss monetary targets more often than a less reputable CB.

Key Words: Central Banking, Reputation, Conservativeness, Monetary Game
JEL Classification: E58; E52; L16

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We thank Zhaohui Chen, Charles Goodhart, Manfred Neumann, Eric Schaling, Dirk Schoenmaker, Jürgen von Hagen, and Chris Waller for comments and suggestions on previous drafts of the paper. We are also grateful to the seminar participants at the Federal Reserve Bank of Cleveland, Indiana University, London School of Economics, the University of Arhuis and the University of Mannheim for helpful comments.

CENTRAL BANK REPUTATION AND CONSERVATIVENESS

1. INTRODUCTION

It is well known that a central bank (CB henceforth) has a strong incentive to ignore whatever commitment to price stability it makes so as to bring about at times a lower unemployment rate. This time inconsistent problem (Kydland and Prescott, 1977; Calvo, 1978) has attracted a great deal of attention in the literature of monetary economics which has proposed solutions, among others, such as CB reputation and CB conservativeness.[1]

The reputation solution is identified with the work by Barro and Gordon (1983). There reputation works perfectly because the private sector enjoys the same information as the CB and, consequently, a "punishment" mechanism works --the trigger strategy-- can completely solve the time inconsistency problem.[2] Canzoneri (1985) extended the Barro and Gordon model by endowing the CB with private information. CB reputation can still work because the private sector can set up a trigger mechanism such that both parties can play the game according to a cooperative strategy so long as the inflation rate is observed to be below a threshold level. If the inflation rate hits the threshold level the game is played noncooperatively for a specified length of time before returning to a cooperative strategy.

[1] Other institutional mechanisms to resolve the time inconsistency problem are legislative rules (Friedman, 1960), giving the CB institutional and personal independence (Neumann, 1991), or writing incentive-compatible contracts (Walsh, 1994 and 1995; Persson and Tabellini, 1993; and Fratianni, von Hagen, and Waller, forthcoming).

[2] Backus and Driffill (1985) study CB reputation in a different framework in which CB reputation does not arrise from the private sector adopting a trigger mechanism.

Rogoff (1985) proposes, instead, a conservative CB as an alternative solution to the time inconsistent problem, that is a CB who cares about price stability more than the private sector. But there is a limit to how conservative a CB can be because the added emphasis on price stability comes at the expense of losing output stabilization. In the presence of a large supply shock a "flexible" CB can be superior to a conservative CB (Lohmann, 1992).

The insights of this literature motivate our paper which asks two fundamental questions. First, can reputation completely solve the CB's time inconsistency problem? Second and more importantly, is there a link between the two alternative solutions to the time inconsistency problem --CB reputation and conservativeness? Our answer to the first question is negative, and to the second is the positive: reputation substitutes for conservativeness. To do so we develop a model based on the synthesis of Canzoneri and Rogoff. As in Canzoneri, we assume that the CB has private but not perfect information about the demand for money so that our model treats monetary shocks in an environment of private information; as in Rogoff, we assume that supply shocks are known to the CB by virtue of rigid wage contracts and that the private sector is concerned both about inflation and output stabilization. On the other hand, we differ from both authors in that our model is based on infinitely repeated games and has two different discount rates, one for the CB and the other for the private sector.

Altogether the paper makes three contributions. First, we demonstrate that the monetary game has two equilibria --the noncooperative and cooperative equilibria-- and we prove that while the noncooperative equilibrium is absolutely robust, there is no assurance that the cooperative equilibrium is robust, that is, there will always be periodic inflationary episodes. Second, since reputation alone cannot solve the time inconsistency problem, the CB may have to be redesigned so as to pursue the price stability objective more vigorously than the private sector. We obtain an optimal degree of CB conservativeness in both the cooperative and noncooperative regime. Third and most importantly, we prove that reputation can substitute for conservativeness but there is a limit to such substitution. If reputation were to work perfectly, there would be no need for a conservative CB. This result provides a general framework to analyze jointly the issues of CB conservativeness and reputation. Our model can explain why low-reputation CBs, like the Banks of Italy, find it worthwhile to peg the exchange rate to the currency of a high-reputation CB and why a highly reputable CB like the Bundesbank can afford to miss monetary targets more often than a less reputable CB. It also shows that CB's independence is not the same as conservativeness and, hence, casts doubt on some of the empirical work on CB independence.

The paper is organized as follows. The model is presented in Section 2. The issue of whether reputation can solve the time inconsistency problem is discussed in Section 3. The optimal degree of CB conservativeness in the cooperative and noncooperative regime is derived in Section 4, where we also prove the substitutability between reputation and conservativeness and provide a unified framework to discuss jointly the issues of CB reputation and conservativeness. The implications of the substitutability between reputation and conservativeness is discussed in Section 5. Conclusions are drawn in Section 6, while formal proofs of all lemmas are relegated to an Appendix.

2. THE MONETARY GAME MODEL

Our point of departure is a model where private sector and the CB play a monetary game repeatedly, as it is true in the well-known Barro-Gordon framework. The structure of the model is described by the following five equations:

$$y_t = \bar{y} + \theta(p_t - w_t) + u_t, \tag{1}$$

$$w_t = p^e_t, \tag{2}$$

$$g_t - \pi_t = \delta_t, \tag{3}$$

$$UP_t = -(y_t - \bar{y})^2 - s(\pi_t - \pi^*)^2, \tag{4}$$

$$UB_t = -(y_t - k\bar{y})^2 - (s + c)(\pi_t - \pi^*)^2, \tag{5}$$

where y_t, p_t, and w_t denote the natural logarithms of output, the price level, and the contract wage rate, respectively; $\bar{y}$ is the equilibrium rate of output corresponding to the natural rate of employment; $\pi_t = p_t - p_{t-1}$ is the rate of inflation and π^* is its socially optimal value; g_t is the rate of growth of the money supply; θ and s are positive constants, $c \in [-s, +\infty)$ denotes the degree of CB conservativeness; while k > 1; u_t and δ_t are two independent random shocks in the production and money markets respectively.

Equation (1) is an output supply function, equation (2) determines the wage rate in terms of the price level expected when labor contracts are negotiated, and equation (3) is the simple money market in growth form that closes the model. The utility functions of the private sector and the CB are given by (4) and (5), respectively. Since the CB deems the output rate generated by private sector, $\bar{y}$, to be too small --because of distortions such as tax rates and unemployment compensation schemes -- it aims at a higher output goal, $k\bar{y}, k > 1$. In our model wage setters are only a subset of private sector which cares about both real wage and output. The utilities of private sector and of the CB differ in the level of target output and the weight assigned to the inflation objective; thus a conflict arises between (4) and (5) concerning the optimal levels of real wage, employment, and output.

Following Canzoneri, we define $\delta_t = e_t + \varepsilon_t$, where e_t is the CB's forecast of the demand for money shock. Three situations can arise based on three different information structures: one in which the CB knows δ_t while the private sector does not; a second in which the CB knows some of δ_t, e_t, because of inside information or superior forecasting but private sector does not; and finally the case where δ_t is unknown to the CB. As in Canzoneri, we concentrate on the second case because it is the most realistic.

The game is played as follows. Private sector forms g_t^e based on the known CB's utility function and the fact that δ_t and u_t are expected to be zero. Subsequently, the CB maximizes its expected utility with respect to g_t by taking g_t^e as given and with a knowledge of the supply shock, u_t, and its own internal forecast of the demand for money, e_t. Finally, information about δ_t, output and inflation is revealed to both the private sector and the CB.

As a result, the noncooperative Bayesian equilibrium in a one-shot game can be solved according to the following steps: taking g_t^e as given, the CB maximizes its expected utility. Through the first order condition, the CB derives its decision rule or optimal strategy as a function of g_t^e. Then, private sector maximizes its utility by taking the CB's decision rule as given. The solution is summarized in Table 1.

Note that the noncooperative equilibrium has an inflation bias equal to y^* / f. As Canzoneri points out, there is an ideal solution --the cooperative and efficient solution-- which would eliminate the inflation bias without changing the rate of output (see Table 1).[3] In this instance both the private sector's and

[3] In the models of Walsh (1995) and Persson and Tabellini the inflation bias can be eliminated through (linear) compensation contracts. However, the bias is not likely to completely disappear in more general setting.

TABLE 1: NONCOOPERATIVE, COOPERATIVE AND CHEATING SOLUTIONS

NONCOOPERATION

$$g_t^{eB,nc} = \pi^* - \frac{\theta}{\theta^2+s+c}u_t + e_t + \frac{y^*}{f} \tag{6a}$$

$$g_t^{e,nc} = \pi^* + \frac{y^*}{f} \tag{6b}$$

$$y_t = \bar{y} + \frac{s+c}{\theta^2+s+c}u_t - \theta\varepsilon_t \tag{6c}$$

$$\pi_t = \pi^* - \frac{\theta}{\theta^2+s+c}u_t - \varepsilon_t + \frac{y^*}{f} \tag{6d}$$

$$EUB_t^{nc} = -(\theta^2+s+c)\sigma_\varepsilon^2 - \frac{s+c}{\theta^2+s+c}\sigma_u^2 - (1+\frac{1}{f})\theta^2 y^{*2} \tag{6e}$$

$$EUP_t^{nc} = -(\theta^2+s)\sigma_\varepsilon^2 - \frac{(s+c)^2+\theta^2 s}{(\theta^2+s+c)^2}\sigma_u^2 - \frac{s}{\theta^2}(\frac{y^*}{f})^2 \tag{6f}$$

COOPERATION

$$g_t^{eB,c} = \pi^* - \frac{\theta}{\theta^2+s+c}u_t + e_t \tag{7a}$$

$$g_t^{e,c} = \pi^* \tag{7b}$$

$$y_t = \bar{y} + \frac{s+c}{\theta^2+s+c}u_t - \theta\varepsilon_t \tag{7c}$$

$$\pi_t = \pi^* - \frac{\theta}{\theta^2+s+c}u_t - \varepsilon_t \tag{7d}$$

$$EUB_t^{c} = -(\theta^2+s+c)\sigma_\varepsilon^2 - \frac{s+c}{\theta^2+s+c}\sigma_u^2 - \theta^2 y^{*2} > EUB_t^{nc} \tag{7e}$$

$$EUP_t^{c} = -(\theta^2+s)\sigma_\varepsilon^2 - \frac{(s+c)^2+\theta^2 s}{(\theta^2+s+c)^2}\sigma_u^2 > EUP_t^{nc} \tag{7f}$$

CHEATING

$$g_t^{eB,ch} = \pi^* - \frac{\theta}{\theta^2+s+c}u_t + e_t + \frac{y^*}{1+f} \tag{8a}$$

$$g_t^{e,ch} = \pi^* \tag{8b}$$

$$y_t = \bar{y} + \frac{s+c}{\theta^2+s+c}u_t - \theta\varepsilon_t + \frac{\theta y^*}{1+f} \tag{8c}$$

$$\pi_t = \pi^* - \frac{\theta}{\theta^2+s+c}u_t - \varepsilon_t + \frac{y^*}{1+f} \tag{8d}$$

$$EUB_t^{ch} = EUB_t^{c} + \frac{\theta^2 y^{*2}}{1+f} \tag{8e}$$

$$EUP_t^{ch} = EUP_t^{c} - \frac{(\theta+s)\, y^{*2}}{1+f} \tag{8f}$$

Legend: The superscript eF denotes the CB's expectation while e denotes the private sector's expectation conditional on information available at the beginning of the contract period; the superscripts nc, c and ch stand for noncooperative, cooperative and cheating solutions, respectively; $y^* = (k-1)\bar{y}/\theta$ and $f = (s+c)/\theta^2$. The rest of the notation is the same as before.

the CB's utility are strictly betteroff. Therefore, the cooperative solution is Pareto dominant and, hence, efficient.

But this cooperative equilibrium is not sustainable if the game is played for only one period because the CB has an incentive to cheat. Indeed, if private sector sets $g_t^e = \pi^*$, the optimal solution is given by (8a) to (8f) in Table 1. Clearly, the CB gains over the cooperative solution and, consequently, the problem of time inconsistency arises.

3. REPUTATION AND TIME INCONSISTENCY PROBLEM

3.1. Could the CB Credibly Precommit?

The main contribution of Barro and Gordon is to have offered the CB reputation solution to the time inconsistency problem. If the monetary game can be played forever, the cooperative strategy is sustainable because the CB can make a credible precommitment or build a reputation.[4] The latter is the key to the solution of the problem of time inconsistency.

Canzoneri extended Barro and Gordon's model by endowing the CB with private information. He argued that the CB can still credibly precommit and solve the problem of time inconsistency through reputation. There is a difference in the equilibrium outcome between the cases without and with private information. In the former the CB chooses its precommitted strategy in every period and the private sector follows a cooperative strategy in every period; the equilibrium outcome recognizes that reputation works perfectly and the CB will never be punished. Under private information the CB, even though it chooses its precommitted strategy before being punished by the private sector,

[4] However, in their model the best rule of zero inflation rate is not enfforceable unless the discount factor is unity.

knows that punishment will occur in later periods. That is, a commitment to an ideal policy does not preclude bouts of higher inflation rates, the so-called reversionary periods.

Canzoneri's argument goes as follows. Wage setters (the private sector in his model) can observe the money demand disturbance, δ_t, at the end of each period but cannot decompose it into the CB's forecast, e_t, and the residual, ε_t. Also $u_t = 0$ in Canzoneri's model. Consequently, wage setters can "punish" the CB by inflating their wages in period $t+1$ whenever they observe g_t being greater than $\pi^* + \delta_t + \bar{\varepsilon} = g_t^{eB,c} + \varepsilon_t + \bar{\varepsilon}$, where $\bar{\varepsilon}$ is a target value chosen by them and $g_t^{eB,c} = \pi^* + e_t$. As a result, the probability of a reversion in period t+1 is[5]

$$P(g_t - g_t^{eB,c} - \bar{\varepsilon}) = Pr(\varepsilon_t < g_t - g_t^{eB,c} - \bar{\varepsilon}), \tag{9}$$

where $P(\bullet)$ is the cumulative distribution function of the CB's forecast error ε_t and $Pr(\bullet)$ denotes probability. Canzoneri argued that the wage setters can find an $\bar{\varepsilon}$ such that if the CB considers raising g_t marginally above $g_t^{eB,c}$, then the expected gain in period t for the CB will be offset by the expected loss in period t+1. By looking at the CB's expected utility over the next two periods starting from a current non-reversionary period,

$$U(g_t, \bar{\varepsilon}) = EUB_t^c + (P)\, EUB_{t+1}^{nc} + (1-P)\, EUB_{t+1}^c, \tag{10}$$

Canzoneri found that it would be incentive compatible for the CB not to renege if $p(-\bar{\varepsilon}) \geq 2/(y^*/f)$. If y^*/f is greater than 2, then an optimal $\bar{\varepsilon}$ can be chosen such that the CB has no incentive to renege. In other words, reputation yields a credible precommitment, even though in equilibrium there may be some periodic reversions.

Our position is that the reputation effect is not sufficiently robust; that is, the CB cannot credibly precommit to policy under a broad range of circumstances.

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[5] See equation (22) in Canzoneri.

3.2. Reputation May Not Work

Our basic point is that the CB, by playing a game for an infinite period, should consider its expected discounted utility. The structure of the game goes as follows.[6] The CB starts with a non-reversionary period (period t) and faces a similar trigger strategy as in Canzoneri. Because in our model there is a product market shock u_t which the private sector can observe at the end of each period, the new trigger strategy is constructed such that if g_t is greater than $\pi^* - \frac{\theta}{\theta^2+s+c}u_t + \delta_t + \bar{\varepsilon} = g_t^{eB,c} + \varepsilon_t + \bar{\varepsilon}$, there will be an inflationary reversion in period $t+1$. As a result, the probability of a reversion is $P(g_t - g_t^{eB,c} - \bar{\varepsilon}) = Pr(\varepsilon_t < g_t - g_t^{eB,c} - \bar{\varepsilon})$. If $g_t < \pi^* - \frac{\theta}{\theta^2+s+c}u_t + \delta_t + \bar{\varepsilon}$, the CB's expected utility will increase by the discount factor, β, times $(1-P)$ times the value of the utility and the game is repeated. If, instead, $g_t > \pi^* - \frac{\theta}{\theta^2+s+c}u_t + \delta_t + \bar{\varepsilon}$ a reversionary period will take place, the CB's utility will increase by P times β times EUB_{t+1}^{nc}. Since a reversion is assumed to last only one period, both players will cooperate in the next period and the expected utility will increase by P times β^2 times the value of the utility. After that the game is repeated. In sum, we have

$$V(g_t,\bar{\varepsilon}) = EUB_t^c + (1-P)\beta V(g_t,\bar{\varepsilon}) + P[\beta EUB_{t+1}^{nc} + \beta^2 V(g_t,\bar{\varepsilon})] , \qquad (11)$$

where $V(g_t,\bar{\varepsilon})$ is the expected discounted utility of the CB. We assume that the CB at time t believes that it will not change money growth in the future. Consequently, its valuation function depends only on the current money growth rate.

Solving for $V(\bullet)$ we obtain

[6] The following is an application of Porter (1983) and Green and Porter's (1984) perfect Bayesian equilibrium strategy to monetary game.

$$V(g_t,\bar{\varepsilon}) = \frac{EUB_t^c + P\beta EUB_{t+1}^{nc}}{1-\beta+P\beta(1-\beta)} = \frac{EUB_{t+1}^{nc}}{1-\beta} + \frac{EUB_t^c - EUB_{t+1}^{nc}}{1-\beta+P\beta(1-\beta)}. \quad (12)$$

Our expression of the CB's expected discounted utility is different from Canzoneri's in that the CB discounts its future utility, $0 < \beta < 1$. The obvious justification is that the head of the CB takes actions today with a view about his reappointment tomorrow. The optimal trigger-money supply g_t will maximize the CB's expected discounted utility $V(\bullet)$ given by equation (12) and subject to the incentive constraint that neither the CB nor the private sector gains by deviating during cooperative periods. Given that the private sector cannot control g_t and has an incentive to cooperate with the CB so long as $g_{t-1} \leq \pi^* - \frac{\theta}{\theta^2+s+c}u_{t-1} + \delta_{t-1} + \bar{\varepsilon}$, the CB's optimal trigger-money supply g_t can be found from its first order condition:

$$\frac{\partial V(g_t,\bar{\varepsilon})}{\partial g_t} = 0.$$

Because $1-\beta > 0$ and $0 < P < 1$, the above condition is equivalent to

$$(1+P\beta)\frac{\partial EUB_t^c}{\partial g_t} - \beta(EUB_t^c - EUB_{t+1}^{nc})\frac{\partial P}{\partial g_t} = 0. \quad (13)$$

Furthermore, if an optimal policy which maximizes the CB's expected discounted utility $V(g_t, \bar{\varepsilon})$, then $V(g_t, \bar{\varepsilon})$ must be concave if evaluated at that policy regime. That is, $V(g_t, \bar{\varepsilon})$ must satisfy the second order condition:

$$\frac{\partial^2 V(g_t,\bar{\varepsilon})}{\partial g_t^2}\Big|_{optimal\,policy} < 0. \quad (14)$$

Equations (13) and (14) yield two lemmas.

Lemma 1: *For any strict concave utility function of the CB, such as equation (5), the equilibrium strategy in a one-shot game,* $g_t^{eB,nc} = \pi^* - \frac{\theta}{\theta^2+s+c}u_t + e_t + \frac{y^*}{f}$ and $g_t^{e,nc} = \pi^* + \frac{y^*}{f}$, is an equilibrium strategy in cooperative periods for any value of $\bar{\varepsilon}$, for any cumulative distribution function $P(g_t - g_t^c - \bar{\varepsilon})$, and for any values of parameters s, c, θ, β, k and $\bar{y}$ within their defined ranges.

Lemma 2: *For any strict concave utility function of the CB, such as equation (5), the ideal policy,* $g_t^{eB,c} = \pi^* - \frac{\theta}{\theta^2 + s + c} u_t + e_t$ and $g_t^{e,c} = \pi^*$, cannot be an equilibrium strategy in cooperative periods for all values of $\bar{\varepsilon}$, for all cumulative distribution functions $P(g_t - g_t^{eF,c} - \bar{\varepsilon})$, and for all values of s, c, θ, β, k and $\bar{y}$, within their defined ranges.

Based on these two important results, it is clear that in the presence of private information, the noncooperative strategy is sustainable as an equilibrium strategy for all kinds of distribution functions of the CB's forecast errors, all kinds of trigger strategies and all values of parameters s, c, θ, β, k and $\bar{y}$ within their defined ranges. In contrast, under the same circumstances, the cooperative strategy, which is the ideal policy, may not be sustainable as an equilibrium strategy. This implies that the problem of time inconsistency may not be easily resolved with reputation, as it is true in a world without private information (Barro and Gordon). Canzoneri's solution turns out to be an incomplete answer to the problem: his trigger strategy may or may not work, depending on the distribution functions of the CB's forecast errors, the trigger strategy and values of other parameters.

The above results can also be interpreted in terms of the robustness of the equilibrium outcomes. In our model, there are two equilibria: the noncooperative equilibrium, if both parties play the noncooperative equilibrium strategy of a one-shot game, and the ideal equilibrium, if the CB plays its ideal policy and private sector plays a trigger strategy which is designed to make the ideal policy incentive compatible. The first equilibrium exists, regardless of the distribution functions of the CB's forecast errors, the trigger strategy and the values of the other parameters. Therefore, the first equilibrium is robust. The second equilibrium, on the other hand, may or may not exist, depending on the distribution functions of the CB's forecast errors, the trigger strategy and the values of the other parameters. Thus, the second equilibrium is not robust. The robustness of one equilibrium, coupled with the non-robustness of the second equilibrium, means that one cannot exclude that both players, even though they start playing the game cooperatively, will switch to a noncooperative equilibrium strategy, due to some disturbance in the economy.

Based on Lemmas 1 and 2 and our above discussion, we can state the following proposition:

Propositio 1: *With private information, reputation alone may not completely solve the time inconsistency problem.*

An alternative solution is to redesign the CB so that it can pursue the price stability objective more vigorously than the private sector. The critical question is how conservative should a CB be. Unlike Rogoff, who considers this issue in a one-shot model and one noncooperative equilibrium, we are able to go beyond the optimal degree of conservativeness in both cooperative and noncooperative equilibria; hence, we can explore the effect of reputation on the degree of CB conservativeness.

4. THE OPTIMAL DEGREE OF CB CONSERVATIVENESS AND REPUTATION

Reputation, while by itself may not be strong enough to resolve the inconsistency problem, has a great deal with the selection of the policy regime.

A noncooperative policy regime, in practice, will prevail when the CB has low reputation (e.g., the Bank of Italy), while a cooperative policy regime will prevail when a CB has a high reputation (e.g., the Bundesbank). This is rather intuitive because the private sector will trust a high-reputation CB to be more sensitive to reversionary inflation than a low-reputation CB.

4.1. Conservativeness in the Noncooperative Policy Regime

In analogy to the CB's expected discounted utility $V(\bullet)$ given by equation (12), the private sector's expected discounted utility is

$$W(g_t, \bar{\varepsilon}) = \frac{EUP_t^c + P\gamma\, EUP_{t+1}^{nc}}{1-\gamma+P\gamma(1-\gamma)} = \frac{EUP_{t+1}^{nc}}{1-\gamma} + \frac{EUP_t^c - EUP_{t+1}^{nc}}{1-\gamma+P\gamma(1-\gamma)}, \tag{15}$$

where $0 \leq \gamma < 1$ is the private sector's discount factor. Based on its expected discounted utility, the private sector determines an optimally conservative CB, that is a CB that best represents the private sector's preferences.

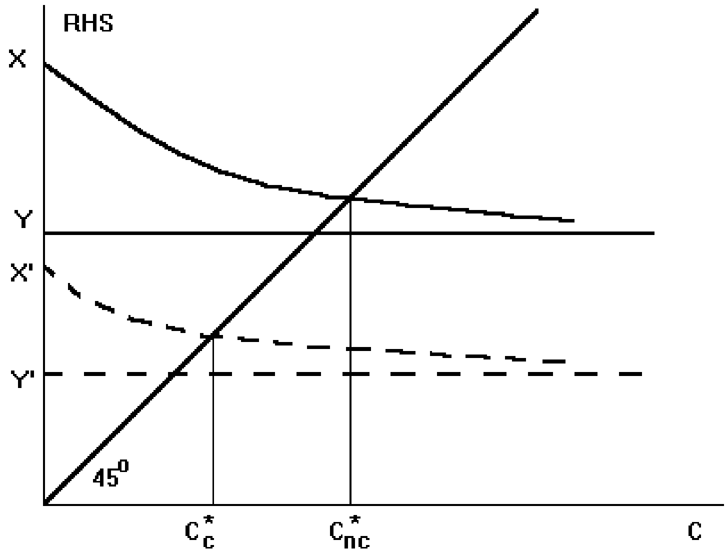
Lemma 3: *In the noncooperative policy regime, where the equilibrium policy is the noncooperative equilibrium strategy in the one-shot game, the optimal degree of CB conservativeness is bounded between* $\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}$ and $(1+\frac{\theta^2}{s})^3\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}$ and equal to:

$$c_{nc}^* = (1+\frac{\theta^2}{s+c_{nc}^*})^3\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}. \tag{16}$$

A graphical solution to (16) will facilitate the interpretation of the optimal degree of conservativeness in a noncooperative regime.[7] The line LHS in Figure

[7] This graphical method is due to Eijffinger and Schaling (1995).

1 is a 45-degree line. The RHS line is monotonically decreasing in c_{nc}^{*}. When c_{nc}^{*} is equal to zero, the RHS of (16) is $(1+\theta^2/s)^3 \, s(k-1)^2 \bar{y}^2/\sigma_u^2$; when c_{nc}^{*} approaches infinity, the RHS of (16) is $s(k-1)^2 \bar{y}^2/\sigma_u^2$. Hence, the optimal value of c_{nc}^{*} is uniquely determined at the single crossing of the LHS and RHS lines. We have thus proved that the optimal degree of conservativeness, as in Rogoff, is strictly positive but finite. But unlike Rogoff, we have also proved that the optimal degree of conservativeness is bounded between $s(k-1)^2 \bar{y}^2/\sigma_u^2$ and $(1+\theta^2/s)^3 \, s(k-1)^2 \bar{y}^2/\sigma_u^2$. An infinitely conservative CB would not suit the interests of the private sector because it would be too inflexible with respect to output stabilization.



Legend: $X = (1 + \frac{\theta^2}{s})^3 \frac{s(k-1)^2 \bar{y}^2}{\sigma_u^2}$, $Y = \frac{s(k-1)^2 \bar{y}^2}{\sigma_u^2}$,

$X' = (1 + \frac{\theta^2}{s})^3 \frac{s(k-1)^2 \bar{y}^2}{\sigma_u^2} \frac{P\gamma}{1+P\gamma}$ and $Y' = \frac{s(k-1)^2 \bar{y}^2}{\sigma_u^2} \frac{P\gamma}{1+P\gamma}$.

FIGURE 1

Note that the RHS curve shifts up when $\theta, k, \bar{y}$ increase and shifts down when σ_u^2 increases. Hence, c_{nc}^* is a positive function of $\theta, k, \bar{y}$, a negative function of σ_u^2, and is insensitive to β, γ and σ_ε^2. A higher supply elasticity θ means that monetary surprises have a larger impact on the deviation of output from its normal value; recognizing this fact, the private sector would benefit from a more conservative CB that would restrain itself in producing monetary surprises. The higher is the CB's output goal k and/or the higher is the natural growth rate $\bar{y}$, the higher is the CB's incentives to create money "surprises"; again, the private sector would like to create a counterweight to such incentives by appointing a more conservative CB. Larger supply shocks necessitate a more flexible response on the part of the CB; hence the private sector would demand a less conservative approach to monetary policy.[8] Neither the discount factor β nor γ are relevant in determining the optimal degree of conservativeness because the private sector is not cooperating with the CB: both parties' payoff in each period is determined by the equilibrium payoff of the one-shot game, where β and γ have no role to play.

The private sector would not want a more conservative CB (than itself) when either k = 1 or $\sigma_u^2 \to \infty$. The intuition is quite straightforward. If k = 1, there is no inflation bias and no need to call for a conservative CB to offset such a bias. If $\sigma_u^2 \to \infty$, the private sector wants maximum flexibility from a CB to stabilize output and, hence, no "additional" emphasis on the inflation target.

4.2. Conservativeness in the Cooperative Policy Regime

For the cooperative strategy to be sustainable the first and second-order conditions --equations (13) and (14), respectively-- must be satisfied. Under these conditions, we can state:

Lemma 4: *The optimal degree of conservativeness of the CB in the cooperative policy regime,* c_c^* is bounded between $\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}\frac{P\gamma}{1+P\gamma}$ and $(1+\frac{\theta^2}{s})^3\,\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}\frac{P\gamma}{1+P\gamma}$ and equal to:

$$c_c^* = (1+\frac{\theta^2}{s+c_c^*})^3\,\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}\frac{P\gamma}{1+P\gamma}. \tag{17}$$

Equation (17) can be easily interpreted with reference to Figure 1. The RHS of (17) consists of two parts: the first two terms are the same as the RHS of (16)

[8] This is the point made by Lohmann.

for each value of c; the second part, $P\gamma / (1 + P\gamma)$, is a positive fraction but less than one. Hence, we can draw the RHS of (17) by shifting downward the RHS curve (indicated by dashes). Consequently, the optimal degree of conservativeness in a cooperative regime is smaller than under noncooperation.

As in the noncooperative policy regime, the optimal degree of conservativeness increases for a high-reputation CB (playing a cooperative game) the higher θ, k, $\bar{y}$ and the lower σ_u^2. The economic intuition is the same as in the case of low reputation. Furthermore, we have the new results that $\partial c_c^* / \partial \gamma > 0$ and $\partial c_c^* / \partial P > 0$.

Under a trigger strategy, the private sector, who cares more about the future and consequently weighs more heavily the CB's future imperfect reputation, wants to delegate a higher degree of conservativeness to the CB. A higher reversionary probability P implies that the CB has less reputation and hence is more likely to cheat, ceteris paribus; as a result, the private sector should delegate a higher degree of conservativeness to the CB. Note that the reversionary probability P is a negative function of the CB's discount factor β, hence, β also affects the private sector's optimal choice of conservativeness in the cooperative equilibrium -- $\partial c_c^* / \partial \beta < 0$. The intuition is also straightforward, if the CB under a trigger strategy cares more about the future, it is less likely to cheat; therefore, it deserves more flexibility to stabilize output growth and the private sector grants it by demanding a lesser degree of conservativeness.

4.3. Reputation Substitutes for Conservativeness

Based on Lemmas 3 and 4 we have the following proposition:

Propositio 2: *Reputation can substitute for conservativeness.*

Proof: The proof consists of two arguments. Argument 1: the optimal degree of conservativeness of a CB with imperfect reputation is less than that of a CB with no reputation, and Argument 2: the optimal degree of conservativeness of a CB with higher imperfect reputation is less than that of a CB with lower reputation.

The proof of Argument 1: For $0 < P < 1$, CB has imperfect reputation and its optimal degree of conservativeness is c_c^*. Based on Figure 1, c_c^* is obviously less than c_{nc}^*, the optimal degree of conservativeness of a CB with no reputation. Using this fact, we have

$$\frac{c_c^*}{c_{nc}^*} = \left(\frac{1 + \dfrac{\theta^2}{s + c_c^*}}{1 + \dfrac{\theta^2}{s + c_{nc}^*}} \right)^3 \frac{P\gamma}{1 + P\gamma} > \frac{P\gamma}{1 + P\gamma}.$$

Hence, $\dfrac{P\gamma}{1 + P\gamma} < \dfrac{c_c^*}{c_{nc}^*} < 1$ for $P > 0$. And for $P = 0$, $c_c^* = 0 < c_{nc}^*$.

The proof of Argument 2: A CB's reputation is lower when the reversionary probability P is higher. From $\partial c_c^* / \partial P > 0$ it is clear that when the CB has imperfect reputation, a less reputable CB should be more conservativeness. Q.E.D.

That is, a high-reputation CB, operating in a cooperative policy environment, can "afford" and, consequently, should be designed to be less conservative in pursuing price-level stability than a no-reputation CB working in a noncooperative environment. Similarly, within the cooperative policy environment, a higher-reputation CB, can "afford" and should be designed to be less conservative than a lower-reputation CB. Indeed, reputation sets another constraint on the CB, and this constraint can substitute for conservativeness in solving the CB's time inconsistency problem. A positive side effect is that both the CB and the private sector gain from the CB's extra flexibility in output stabilization.

Note that there is a limit for the substitution between a CB with imperfect reputation and that with no reputation, the ratio c_c^* / c_{nc}^* being bounded between a small positive number $P\gamma/(1 + P\gamma)$ and 1 for $0 < P < 1$ and $0 < \gamma < 1$. This is because in the cooperative equilibrium there will always be periodic inflationary episodes, even if the CB were always running the ideal monetary policy. In other words, in the case of $P > 0$ reputation does not work perfectly, the public can still gain from choosing a conservative CB even if the CB is reputable.

When reputation works perfectly, i.e., $P = 0$, the price stability can always be achieved in every period, as a result the public does not need a conservative CB. In this case a conservative CB would harm the private sector because of its insufficient flexibility in stabilizing output. But reputation can work perfectly only if the CB has perfect information about all shocks, an unlikely event in the real situation. In practice, a reputable CB that cares about price stability more than the private sector is always desirable from the private sector's perspective.

Similarly, if the private sector does not value the future, i.e., $\gamma = 0$, it has no use for a conservative CB. This is because in our model both the private sector and the CB start playing a cooperative game. The fact that the future has no value to the private sector is equivalent to saying that reputation works perfectly.

4.4. A Unified Framework for CB Reputation and Conservativeness

If cooperative solution is not feasible, there is no reputation at all, then the optimal degree of CB conservativeness is in the noncooperative policy regime and is equal to c_{nc}^*; if there is some but not perfect reputation, Lemma 4 above shows that the optimal degree of CB conservativeness is in the cooperative policy regime and is equal to c_c^*, and $P\gamma/(1 + P\gamma) < c_c^* / c_{nc}^* < 1$; and if there is perfect reputation, Proposition 2 above shows that the optimal degree of CB conservativeness is in the cooperative policy regime and is equal to 0.

Figure 2 summarizes our result. There are three zones there. Zone 1 represents the "no reputation" regime, where the optimal degree of conservativeness is the highest. Zone 2 is the "imperfect reputation" regime, where c_c^* is bounded between 0 (in the limit) and less than c_{nc}^*. The discontinuity between Zone 1 and Zone 2 occurs because in the "no reputation" regime the CB and the private sector played the non-cooperative game always (i.e., $P = 1$), whereas in the "imperfect reputation" regime the game is being play cooperatively (i.e., $0 \leq P < 1$). A "first push" from outside may be necessary to convince both parties to play the game cooperatively. Zone 3 represents the "perfect reputation" regime, where the optimal degree of conservativeness is equal to zero.

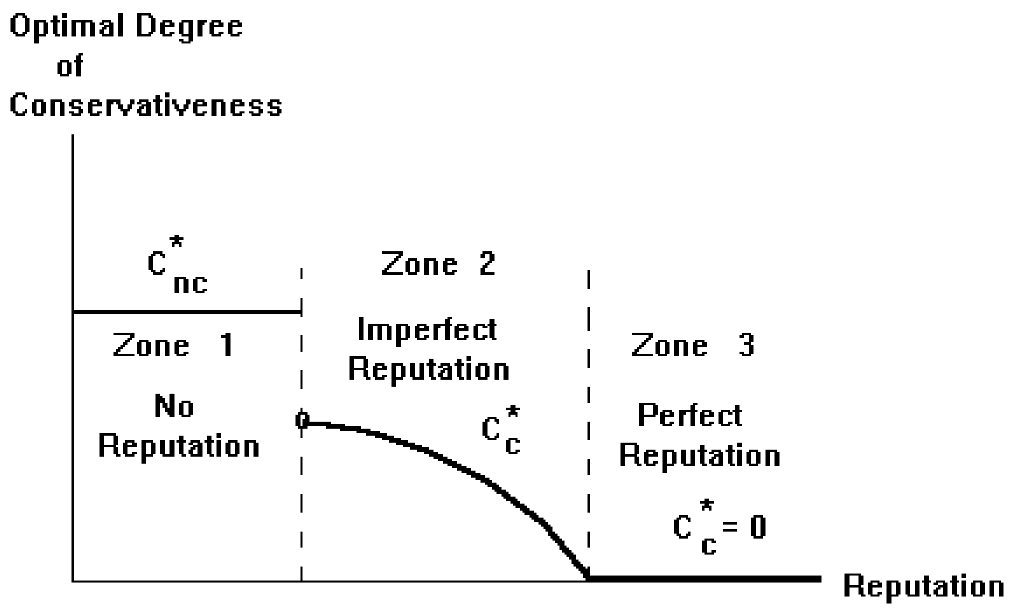


FIGURE 2

The figure provides a useful summary of the literature on this topic. Barro and Gordon, and the perfect information monetary game literature, fit in Zone 3, where reputation works perfectly and there is no need for a conservative CB. Canzoneri, as we re-interpret, and the private information literature fit in Zone 2, where reputation works imperfectly and the public can always gain from a conservative CB. Rogoff, Lohmann and the literature focusing on CB's conservativeness and precommitment belong in Zone 1, where reputation is excluded and the public can only rely on a conservative CB. We now explore some theoretical and empirical implications of our main result that reputation substitutes for conservativeness.

5. IMPLICATIONS

5.1. Exchange-Rate Pegging

Our substitution result provides a theoretical justification for the working of exchange rate arrangements, such as the Exchange Rate Mechanism (ERM) in the European Monetary System. In the ERM, a low-reputation CB, like the Bank of Italy, relinquished monetary policy independence in favor of pegging their currencies to the Deutsche mark.[9] The advantage of letting the Bundesbank determine monetary policy is that its high reputation can be transferred to other participating CBs. Such a transfer of reputation may provide a sort of "first push" to other CBs and create an environment where reputation can be built. This, in turn, would allow these CBs to become less conservative in pursuing price level stability objectives. Naturally, the reputation transfers are incomplete if the peg is changed, as it happened frequently in the history of the ERM. Our result is consistent with von Hagen's (1992) findings that both high and low-reputation CBs can gain from an ERM-like arrangement.

5.2. Monetary Targeting and Reputation

Since conservativeness is the complement of flexibility, it follows that it is the Bundesbank, and not the Bank of Italy, that can afford to deviate more frequently from the announced values of the money growth targets, where the difference between actual and announced money growth stands as a proxy of the CB's flexibility in adjusting to unanticipated shocks. Both CBs announce yearly monetary targets.The Bundesbank is very methodical in justifying the monetary targets in terms of target values of inflation, output growth, and an estimate of changes in the velocity of money circulation (Issing, 1992; Neumann and von

[9] Italy, as well as the UK, left the ERM in September, 1992.

Hagen, 1992). The Bank of Italy does not justify its monetary targets, although it makes reference to the government's target inflation rate. One thing is clear: the Bundesbank sets its own target inflation rate, the Bank of Italy does not.

TABLE 2: MONETARY TARGETING OF THE BUNDESBANK AND THE BANK OF ITALY

	Bundesbank		Bank of Italy	
Years % M	% M target	% M realized	% M target	realized
1984	4.0 - 6.0	4.60	11.00	12.30
1985	3.0 - 5.0	4.50	10.00	11.10
1986	3.5 - 5.5	7.70	7 - 11	9.60
1987	3.0 - 6.0	8.10	6 - 9	8.60
1988	3.0 - 6.0	6.70	6 - 9	8.90
1989	5.0	5.5	6 - 9	9.50
1990	4.0 - 6.0	19.7	6 - 9	9.90
1991	3.0 - 5.0	6.3	5 - 8	9.00
1992	3.5 - 5.5	7.5	5 - 7	6.00
1993	4.5 - 6.5	10.9	5 - 7	7.90
1994	4.0 - 6.0	1.6	5 - 7	2.80

Legend: % M denotes percentage change of the money stock. For Germany M is central bank money up to 1987 and then M3; for Italy it is M2. For sources see Fratianni (1995).

Table 2 shows the values of the money growth targets and their realized values for the period 1984-1994 of the two CBs. During these eleven years the Bundesbank missed its money targets 9 times, whereas the Bank of Italy only 7 times. We also calculated the average absolute deviation from the midpoint of the money growth target range from the realized growth rate, as a ratio of the target value: this was more than three times higher for the Bundesbank (0.74) than for the Bank of Italy (0.22). The Bundesbank appears to have had a higher propensity to miss the money targets than the Bank of Italy. Yet, these large individual deviations have not prevented the Bundesbank from achieving a longrun rate of inflation close to its declared goal of approximately 2 per cent (Issing; Neumann and von Hagen; Fratianni, 1995). We consider this evidence suggestive of the substitution that exists between reputation and conservativeness.

5.3. Independence vs. Conservativeness

Our paper has underscored the solution to the problem of time inconsistency by rearranging the CB's preferences. This can be done by creating an independent branch of government which can pursue price stability without any interference from other branches of government.[10] The CB is to be independent from government, but not from the private sector. It is the latter that decides the optimal degree of CB conservativeness. The independent (from government) CB is able to respond to the public's wishes by being insulated from the pressure of politics and the attendant problem of time inconsistency. The higher the degree of independence of the CB, the more reputable is the institution in the sense that it has the trust of the people. There is a consensus in the empirical literature on CB independence that the Bundesbank is a very independent and very reputable CB; on the contrary, the Bank of Italy was not an independent CB until the reforms of the early 1990s and its reputation was considerably lower than the Bundesbank's (Cukierman, 1992; Alesina and Summers, 1993; Fratianni and Huang, 1994).[11]

Our main result that reputation/independence substitutes for

[10] See Goodhart (1994) on political pressure from the private sector to the CB, and Fratianni, von Hagen, and Waller for the principal-agent relationship between the private sector and the CB.

[11] Fratianni and Huang constructed an independence index based on nine different measures of CB independence, including those in Cukierman and Alesina and Summers.

conservativeness makes it imperative to differentiate empirically independence from conservativeness. As a result, the conventional interpretation in the literature that a more independent CB is also a more conservative CB, e.g., see Eijffinger and Schaling, is not justified.

6. CONCLUSIONS

Noncooperative equilibrium, based on both players playing their equilibrium strategies in a one-shot game, is robust under any conditions. That is, the noncooperative strategy is an equilibrium strategy regardless of the distribution function of the CB's forecast errors of the demand-for-money function, the trigger strategy and the values of the other parameters of the model. In contrast, the ideal policy, which is the cooperative strategy or time-inconsistent policy in a one-shot game, may or may not be an equilibrium strategy.

We have shown that, after adding private information to Barro and Gordon's model, there is no assurance that reputation may work for the CB. Therefore, the solution to the problem of time inconsistency cannot rely on letting the CB and private sector play the monetary game for an infinite period of time. Our results extend those of Canzoneri.

An alternative solution is to delegate a more conservative CB to conduct monetary policy, where conservativeness is defined as the additional weight the CB places on the price-level stability objective. We can think of conservativeness as the complement of flexibility in stabilizing output around a trend. We found that there is an optimal degree of conservativeness the private sector desires in its CB. Our results on the optimal degree of CB conservativeness extend those of Rogoff in two ways. First, our results are obtained from a model where the CB and private sector play the game repeatedly; second, we solve for the optimal degree of conservativeness under both noncooperation and cooperation.

We proved an interesting and intuitive result: reputation can substitute for a certain degree of conservativeness. Unless reputation works perfectly, a conservative CB that cares about price stability more than the private sector is in the private sector's interests. Our model provides a general framework to resolve the problem of CB's time inconsistency. The two alternative solutions proposed in the literature, i.e. reputation and conservativeness, are special cases of ours. Our results can explain why low-reputation CBs, like the Bank of Italy, find it worthwhile to peg the exchange rate to the currency of a high-reputation CB, like the Bundesbank, and it explains why a highly reputable CB can afford to miss monetary targets more often than a less reputable CB. Our finding also implies that the conventional interpretation of treating an independent CB as being equivalent to a conservative CB is not justified.

APPENDIX

Proof of Lemma 1: For any value of $\bar{\varepsilon}$, for any distribution function $P(g_t - g_t^{eF,c} - \bar{\varepsilon})$, and for any values of parameters s, c, θ, β, k and $\bar{y}$, within their defined ranges, if both private sector and the CB are playing a noncooperative strategy in every period, then $EUB_t^c = EUB_t^{nc}$ at EUB_t^{nc}. As a result, $\partial EUB_t^{nc}/\partial g_t = 0$ and $EUB_t^{nc} = EUB_{t+1}^{nc}$ and equation (13) is always satisfied. Furthermore, for any value of $\bar{\varepsilon}$, for any distribution function $P(g_t - g_t^{eB,c} - \bar{\varepsilon})$ and for any value of s, c, θ, β, k and $\bar{y}$, within their defined ranges,

$$\frac{\partial^2 V(g_t, \bar{\varepsilon})}{\partial g_t^{\,2}}\Big|_{g_t = g_t^{eB,nc}} = \frac{\dfrac{\partial^2 EUB_t^c}{\partial g_t^{\,2}}\Big|_{g_t = g_t^{eB,nc}}}{1 - \beta + P\beta(1-\beta)} < 0, \tag{A1}$$

because of $1-\beta + P\beta(1-\beta) > 0$ for $0 < \beta < 1$ and $0 \le P \le 1$ and the strict concavity of the CB's utility function. Therefore, the equilibrium strategy in a one-shot game, $g_t^{eB,nc} = \pi^* - \dfrac{\theta}{\theta^2 + s + c} u_t + e_t + y^* / f$ and $g_t^{e,nc} = \pi^* + y^* / f$, is an equilibrium strategy in cooperative periods for any value of $\bar{\varepsilon}$, for any cumulative distribution function $P(g_t - g_t^{eF,c} - \bar{\varepsilon})$ and for any value of s, c, θ, β, k and $\bar{y}$, within their defined ranges. Q.E.D.

Proof of Lemma 2: By evaluating equation (13) at $g_t^{eB,c} = \pi^* - \dfrac{\theta}{\theta^2 + s + c} u_t + e_t$ and $g_t^{e,c} = \pi^*$, we obtain

$$(1 + P\beta)\frac{\partial EUB_t^c}{\partial g_t}\Big|_{g_t = g_t^{eB,c}} - \Big[\beta(EUB_t^c - EUB_{t+1}^{nc})\frac{\partial P}{\partial g_t}\Big]\Big|_{g_t = g_t^{eB,c}} = 0,$$

or

$$(1 + P\beta)[2\theta(k-1)\bar{y}] - \beta\frac{\theta^2}{s+c}(k-1)^2 \bar{y}^2 p(-\bar{\varepsilon}) = 0,$$

which implies

$$p(-\bar{\varepsilon}) = \frac{2[1 + P(-\bar{\varepsilon})\beta](s+c)}{\beta\theta(k-1)\bar{y}}, \tag{A2}$$

where $p(-\bar{\varepsilon})$ and $P(-\bar{\varepsilon})$ are the probability density and cumulative distribution functions evaluated at $-\bar{\varepsilon}$, respectively. Furthermore, if g_t is an incentive compatible and optimal policy which maximizes the CB's expected discounted utility $V(g_t, \bar{\varepsilon})$, then $V(g_t, \bar{\varepsilon})$ must be concave at $g_t^{eB,c} = \pi^* - \frac{\theta}{\theta^2 + s + c} u_t + e_t$ and $g_t^{e,c} = \pi^*$. That is, we need to verify whether

$$\frac{\partial^2 V(g_t, \bar{\varepsilon})}{\partial g_t^{\ 2}}\Big|_{g_t = g_t^{eB,c}} < 0 . \tag{A3}$$

Equation (A3) is equivalent to

$$-2[(1 + P(-\bar{\varepsilon})\beta](\theta^2 + s + c) - \beta \frac{\theta^2}{s+c}(k-1)^2 \bar{y}^2 \frac{\partial^2 P(-\bar{\varepsilon})}{\partial g_t^{\ 2}} < 0 ,$$

or

$$2[(1 + P(-\bar{\varepsilon})\beta](\theta^2 + s + c) + \beta \frac{\theta^2}{s+c}(k-1)^2 \bar{y}^2 \frac{\partial^2 P(-\bar{\varepsilon})}{\partial g_t^{\ 2}} > 0 . \tag{A4}$$

Equations (A2) and (A4) are the necessary and sufficient condition for the ideal policy, $g_t^{eB,c} = \pi^* - \frac{\theta}{\theta^2 + s + c} u_t + e_t$ and $g_t^{e,c} = \pi^*$, or the incentive compatible and optimal policy which maximizes the CB's expected discounted utility $V(g_t, \bar{\varepsilon})$. Since the first item in (A4) is always positive, a sufficient condition for equation (A4) to be satisfied is

$$\frac{\partial^2 P(-\bar{\varepsilon})}{\partial g_t^{\ 2}} \geq 0 . \tag{A5}$$

Equations (A2) and (A4) set two constraints on the value of $\bar{\varepsilon}$, the cumulative distribution function $P(g_t - g_t^{eB,c} - \bar{\varepsilon})$ and the values of parameters s, c, θ, β, k and $\bar{y}$. If either equation (A2) or equation (A4) cannot be satisfied for any reason, then the ideal policy cannot be sustained as the noncooperative equilibrium strategy. Q.E.D.

Proof of Lemma 3: The private sector's expected discounted utility is given by equation (15),

$$W(g_t, \bar{\varepsilon}) = \frac{EUP_t^c + P\gamma EUP_{t+1}^{nc}}{1 - \gamma + P\gamma(1-\gamma)} = \frac{EUP_{t+1}^{nc}}{1-\gamma} + \frac{EUP_t^c - EUP_{t+1}^{nc}}{1 - \gamma + P\gamma(1-\gamma)} . \tag{A6}$$

If the equilibrium policy is the noncooperative equilibrium strategy in the one-shot game, then we have $EUP_t^{nc} = EUP_t^{c}$ and $EUP_{t+1}^{nc} = EUP_t^{nc}$. As a result,

$$W^{nc} = W(g_t^{eB,nc}, \bar{\varepsilon}) = \frac{EUP_{t+1}^{nc}}{1 - \gamma}. \tag{A7}$$

Hence $\frac{\partial W^{nc}}{\partial c} = - \frac{2 \quad 2}{} \frac{2 \atop u}{2 \qquad 3} \frac{2 - 2}{3}$

$\frac{\partial^2 W^c}{\partial c^2}|_{c=c_c^*} = -\frac{2\theta^2}{1-\gamma}[\frac{(\theta^2+s)\sigma_u^2}{(\theta^2+s+c)^4} + \frac{s(k-1)^2\bar{y}^2}{(s+c)^4}\frac{P\gamma}{1+P\gamma}(\frac{3}{s+c} - \frac{2}{\theta^2+s+c})] < 0$. The lower bound of c_c^* is $\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}\frac{P\gamma}{1+P\gamma}$ and the upper bound of c_c^* is $(1+\frac{\theta^2}{s})^3\frac{s(k-1)^2\bar{y}^2}{\sigma_u^2}\frac{P\gamma}{1+P\gamma}$. And its unique solution is determined by (A11).

Q.E.D.

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