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INTERNATIONAL POLICY GAMES IN A SIMPLE MACROECONOMIC MODEL WITH INCOMPLETE INFORMATION: SOME PROBLEMS OF CREDIBILITY, SECRECY AND COOPERATION

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Summary

A stylized analytical model of two interdependent countries is used to examine game aspects of international macroeconomic policy design. The dominant theme centres on credibility problems arising from intrinsic uncertainty and the incentive for players to conceal or misrepresent private information in order to disguise their intention to export inflation abroad. By focusing on the precise incentive structure which motivates secrecy, together with the design of enforcement mechanisms for punishing such behaviour, separating and pooling equilibria are identified which explicate conditions under which private information is revealed. These equilibria describe the state of inflation, output and the exchange rate and indicate circumstances under which either or both countries may experience a recession from non-cooperative behaviour. Implications are drawn for cooperative decision making, emphasizing the dual role of cooperation in terms of both policy coordination and information coordination. This framework also demonstrates how various independent research can be viewed collectively within a single general paradigm.

Keywords: Games, credibility, cooperation, information.

1. Introduction

A growing research programme in international economics is concerned with the strategic aspects of international policy making, emphasizing the theory of games as a natural characterization of national policy design in a world of interdependent countries.[1] Recent contributions typically involve numerical dynamic model simulations for the purpose of evaluating the potential inefficiencies of non-cooperative behaviour between countries and the incentives for cooperation and international policy coordination (Buiter and Marston, 1985; Currie and Levine, 1984, 1986a,b; Hughes-Hallett, 1984; Miller and Salmon, 1984a,b; Oudiz and Sachs, 1984a,b; Sachs, 1983). The conclusions reached from this exciting research are ambiguous, indicating potentially large gains from cooperation in some circumstances whilst fairly small gains (and possibly net losses) in others.[2]

Much less research has been devoted to examining the types of issues recently explored within a closed (or small open) economy context concerning credibility problems and the properties of sequential equilibria in repeated games sustained by threat strategies and the information structure conditioning beliefs under uncertainty (Andersen, 1985, 1986; Backus and Driffill, 1985a,b; Barro, 1986; Barro and Gordon, 1983; Canzoneri, 1985; Cukierman and Meltzer, 1986; Vickers, 1987).[3] It is not implausible to argue, however, that these and related issues are likely to be far more acute, and less susceptible to some problems of interpretation, in an international setting where the game is between different national governments. A prevalent source of controversy which lies in the normative aspects of the literature centres on the interpretation of a government's utility function as a social welfare function when private agents dislike being cheated by the policy maker or when there are different types of policy maker. By contrast, there is no *a priori* reason (and probably strong arguments against) why the preferences of different national governments should coincide and therefore a rich source of potential conflict in an international environment. There is also some debate over the interpretation of a singular (sometimes fairly sophisticated) strategy on the part of many atomistic agents who are treated as a monolithic private sector but who are precluded from acting collusively.[4] Finally, one might argue that the informational assumptions either implicit or explicit in much of the most recent research are more appropriate in an international setting which is perhaps more conducive to the prospect and persistence of information asymmetries.

The latter point is of particular interest because it motivates the idea of *informational* games as opposed to just *policy* games, and because of its implications for international cooperation and policy coordination. To be sure, in a repeated game with asymmetric information, there may be strong incentives for players to conceal their own private information in order to manipulate an opponent's belief in such a way that they can eventually be exploited. Unless there is some reassurance that potential members in an agreement have no incentive to withhold (or even misrepresent) relevant information, the game will be characterized by learning and the preference for secrecy would seem to preclude any negotiations on cooperative policy design. This is to say that a pre-requiste for policy coordination is the revelation of information or that cooperation has a dual role in coordinating both policies and information.

This paper is designed to explore the issues raised above, taking up some conjectures in an earlier analysis (Blackburn, 1987b) and using a stylized analytical model of two strategically interdependent economies to focus attention on the precise incentive structure which induces players to conceal private information. This model is contained in section 2. Section 3 identifies the first-best outcome under cooperation and illustrates the basic problem of credibility in the form of an incentive for one country to seek gains by exporting inflation abroad through a surprise exchange rate appreciation. Given that the rival policy authority understands this incentive, an inferior equilibrium results from beggar-thy-neighbour policies (Oudiz and Sachs, 1984a; Sachs, 1983). This section also illustrates the folk theorem in repeated full information games. Uncertainty in this model takes the form of asymmetric information about players' preferences (what is termed here as intrinsic uncertainty) and the main focus of the paper is on the motivation for players to conceal their identity and maintain these idiosyncracies in the information structure.[5] Section 4 considers an 'announcement game' which draws an analogy with principal/agent problems, seeking enforcement mechanisms which coerce a rival into revealing its information and which support an equilibrium which is incentive compatible. Section 5 considers a 'signalling game' where the incentives for players themselves to reveal their own identity is examined. In both of these cases, there is a separating equilibrium in which information is revealed and a pooling equilibrium in which preferences remain unidentified. Whilst each of these approaches have been considered independently in the past, it is possible to combine them and identify conditions under which pooling dominates for both players and the equilibrium is characterized by learning. Section 6 contains some concluding remarks about cooperation and its dual role alluded to earlier.

2. The Analytical Framework

The basic environment in which the games take place involves spatially separated but interdependent players (countries or governments) operating under a flexible exchange rate system. A particularly tractable representation involves two symmetric countries and a world economy which has the reduced form

$$y_t(x_t, x_t^*) = \alpha_1 x_t + \alpha_2 x_t^* \tag{2.1}$$

$$y_t^*(x_t, x_t^*) = \alpha_1 x_t^* + \alpha_2 x_t \tag{2.2}$$

$$p_t(x_t, x_t^*) = \beta(x_t - x_t^*) = -p_t^*(x_t, x_t^*) \tag{2.3}$$

$$s_t(x_t, x_t^*) = \gamma(x_t - x_t^*) \tag{2.4}$$

(α_1, β, $\gamma > 0$; $\alpha_2 \gtrless 0$). Variables are measured as deviations from the mean and are defined as follows with an asterisk denoting a foreign counterpart: y is the rate of growth of output, p is the rate of inflation, s is the rate of depreciation and x is a policy instrument (taken here as the rate of growth of the money supply). Time is measured discretely and is indexed by $t = \{1,\ldots,T\}$.[6] It is assumed that $\alpha_1 > |\alpha_2|$, implying that the policy instrument of a particular country has a greater effect upon the output of that country than upon the output of the other country.

This reduced form, or some variant thereof, has been employed by Blackburn (1987b) and Laskar (1984), amongst others, and is consistent with a class of fairly standard open economy macroeconomic models which one generally finds in the existing literature. The underlying structure contains aggregate demand and portfolio balance relationships, an uncovered interest parity condition and a price-wage-exchange rate feedback nexus, the symmetry assumption explaining the symmetric effects of different policy instruments on variables in the reduced form. In order to focus attention on the strategic interactions between national policy makers, which may become quite complicated under imperfect information, the model abstracts from dynamics of adjustment and eschews an independent role for private sector strategic behaviour. As indicated above, the model (and the preference technology of governments to be described below) are also in the generation of models which posit 'plausible' macroeconomic relationships rather than reflecting explicit optimizing behaviour.[7]

The preferences of each country are described as follows. The domestic economy is assumed to possess an internal objective (stabilizing inflation) and an external objective (stabilizing exchange rate fluctuations) which may be summarized by a quadratic loss function of the form $\frac{1}{2}\delta_1 s_t^2 + \frac{1}{2}\delta_2 p_t^2$ (δ_1, $\delta_2 > 0$). The foreign country also has internal and external objectives but is assumed to prefer lower foreign inflation, in which case its disutility is approximated by $\frac{1}{2}\delta_1^* s_t^2 + \delta_{2i}^* p_t^* + \frac{1}{2}\delta_3^* x_t^{*2}$ (δ_1^*, $\delta_{2i}^* \geq 0$; $\delta_3^* > 0$; $i = 1,2$) where the final term is also a measure of control effort and where $i = 1,2$ refers to different types of foreign government (to be elaborated upon below). Given the reduced form in (2.1)-(2.4), these preferences may be written as

$$\Omega_t(x_t, x_t^*) = \tfrac{1}{2}\omega(x_t - x_t^*)^2 \tag{2.5}$$

$$\Omega_{it}^*(x_t, x_t^*) = \tfrac{1}{2}\omega_1^*(x_t - x_t^*)^2 - \omega_{2i}^*(x_t - x_t^*) + \tfrac{1}{2}\omega_3^* x_t^{*2} \quad (i=1,2) \tag{2.6}$$

(ω, $\omega_3^* > 0$; ω_1^*, $\omega_{2i}^* \geq 0$; $i=1,2$). The distinction between different types of foreign government, alluded to above, becomes important when considering the implications of informational asymmetries. It is assumed that $\omega_{21}^* < \omega_{22}^*$ so that a type-2 foreign government prefers lower foreign inflation than a type-1 which preferences coincide with those of the domestic government when $\omega_{11}^* = 0$.

In general, the objective functional for each country is an expected discounted sum of the disutilities in (2.5)-(2.6) and the decision problem is

$$\min_{x_t} \Lambda(x_0,\ldots,x_T;x_0^*,\ldots,x_T^*) = E \sum_{t=0}^{T} \lambda^t \Omega_t(x_t,x_t^*) \qquad (2.7)$$

$$\min_{x_t^*} \Lambda_i^*(x_0,\ldots,x_T;x_0^*,\ldots,x_T^*) = E_i^* \sum_{t=0}^{T} \lambda^t \Omega_{it}^*(x_t,x_t^*) \ (i=1,2) \qquad (2.8)$$

$(0 \leq \lambda \leq 1)$ subject to the 'rules of the game' and where the expectations operators are conditioned on the information set for each player.[8] In the absence of any inter-temporal links, the decision problem reduces to piecewise optimization; for the current model, inter-temporal aspects arise from repeated games and strategic behaviour involving 'memory'.

3. Cooperative and Non-Cooperative Behaviour in Full Information Games

Before turning to the main theme of the paper on imperfect information, it is useful to consider first the basic problem of credibility in a full information one-shot game and how cooperative behaviour may be enforced in a repeated game.

3.1 Cooperation, Defection and Credibility in a Single-Stage Game

It is obvious from (2.5) that the domestic government will choose the strategy

$$x_t(x_t^*) = Ex_t^* \qquad (3.1)$$

and since there is no uncertainty, $Ex_t^* = Ex_{it}^*$ $(i=1,2)$ (i.e. the forecast of foreign policy is merely the forecast of the strategy associated with a known type of foreign government). A cooperative equilibrium occurs when a foreign government of either type announces and commits itself to a strategy so that $x_t(x_t^*) = Ex_{it}^* = x_{it}^*$ $(i=1,2)$ and the foreign government chooses

$$x^*_{it} = \bar{x}^*_i = 0 \qquad (i=1,2) \qquad (3.2)$$

yielding the first-best outcome in which all variables are at their mean values and

$$\Omega^*_{it} = \bar{\Omega}^*_i = 0; \quad \Omega_t = \bar{\Omega} = 0 \qquad (i=1,2) \qquad (3.3)$$

In the absence of binding commitments, however, a foreign government can improve its payoff by unilaterally defecting. To see this, note that the optimal strategy for any given x_t is

$$x^*_{it}(x_t) = (\omega^*_1 x_t - \omega^*_{2i})/(\omega^*_1 + \omega^*_3) \qquad (i=1,2) \qquad (3.4)$$

Hence, given that x_t is set on the assumption that $x^*_{it} = \bar{x}^*_i$, a 'cheating' strategy involves

$$x^*_{it} = \tilde{x}^*_i = -\omega^*_{2i}/(\omega^*_1 + \omega^*_3) \qquad (i=1,2) \qquad (3.5)$$

$$\Omega^*_{it} = \tilde{\Omega}^*_i = -\omega^{*2}_{2i}/2(\omega^*_1+\omega^*_3); \quad \Omega_t = \tilde{\Omega}_t = \omega\omega^{*2}_{2i}/2(\omega^*_1+\omega^*_3)^2 \qquad (i=1,2) \qquad (3.6)$$

The source of the gain from cheating is a relatively contractionary foreign monetary policy which causes a surprise appreciation in foreign currency. This exports inflation to the domestic economy, has a contractionary effect on foreign output and may increase or reduce domestic output depending upon whether $\alpha_2 \gtrless 0$. It follows that the only sustainable equilibrium is when the foreign government treats as parametric the setting of x_t. The outcome is an inferior discretionary (or open loop Nash) equilibrium in which $x_t(x^*_t) = Ex^*_{it} = x^*_{it}$ (i=1,2) in (3.4) and

$$x^*_{it} = \hat{x}^*_i = -\omega^*_{2i}/\omega^*_3 \qquad (i=1,2) \qquad (3.7)$$

$$\Omega^*_{it} = \hat{\Omega}^*_i = \omega^{*2}_{2i}/2\omega^*_3; \quad \Omega_t = \hat{\Omega} = 0 \qquad (i=1,2) \qquad (3.8)$$

In this case, the lack of credibility of foreign government announcements nullifies any opportunity to export inflation and the equilibrium is characterized by excessively contractionary domestic and foreign policies.

The essential problem confronting the domestic government in a full information game, therefore, is whether or not a known type of rival intends to renege on its promises. In the absence of binding commitments, one must seek (informal) mechanisms which substitute for formal commitments and enforce cooperation.

3.2 Threat and Reputation in a Multi-Stage Game

A well-known folk-theorem states that the cooperative equilibrium in a one-shot full information game can be sustained as a non-cooperative Nash equilibrium in a repeated game provided the rate of discount is not too high. As a simple example of this here, consider the step function

$$x_t(x^*_t) = E(x^*_{it}|x^*_{it-1}) = \begin{cases} \bar{x}^*_i & \text{if } x^*_{it-1} = \bar{x}^*_i \\ \hat{x}^*_i & \text{if } x^*_{it-1} \neq \bar{x}^*_i \end{cases} \qquad (i=1,2) \qquad (3.9)$$

which is merely a 'tit-for-tat' strategy, stating that good behaviour by a foreign government induces good behaviour by the domestic government whilst bad behaviour is responded to in a likewise fashion. For $T = \infty$, define

$\bar{\Lambda}^*_i = (\bar{\Omega}^*_i + \lambda\bar{\Omega}^*_i + \lambda^2\bar{\Omega}^*_i + \ldots)$ as the discounted loss associated with

adhering to $x^*_{it} = \bar{x}^*_i$ and $\tilde{\Lambda}^*_i = (\tilde{\Omega}^*_i + \lambda\hat{\Omega}^*_i + \lambda^2\hat{\Omega}^*_i + \ldots)$ (i=1,2) as the discounted loss associated with defecting in period t and being forced to play Nash subsequently.[9] In addition, let $\underline{\Omega}_i^* = \omega_{2i}^{*2}(\omega_1^* + 2\omega_3^*)/2\omega_3^*$ be the per-period payoff when $x_{it}^* = \bar{x}_i^*$ but $x_t = \hat{x}_i^*$ so that $\bar{\tilde{\Lambda}}_i^* = (\tilde{\Omega}_i^* + \lambda\underline{\Omega}_i^* + \lambda^2\tilde{\Omega}_i^* + \ldots)$ (i=1,2) is the discounted disutility associated with the sequence involving alternating between defection and regaining reputation. The cooperative solution can be sustained if $\bar{\Lambda}_i^* \leq \tilde{\Lambda}_i^*$ and $\bar{\Lambda}_i^* \leq \approx{\Lambda}_i^*$, both of which are satisfied if $\lambda \geq \omega_3^*/(\omega_1^* + 2\omega_3^*)$; any higher rate of discount means that the punishment for defection, which occurs in the future, is simply not severe enough.

This analysis offers some consolation to those who are eager to realise the benefits from cooperation, reflecting the majority opinion on international policy design in that, under full information, problems of credibility and enforcing cooperation may be resolved fairly easily by simple incentive schemes. One major critism, however, centres on the assumption of full information which effectively trivializes the game by limiting the scope for deception on the part of rivals, the preferences (and therefore dominant strategy) of which are known. It is possible to argue that a more appropriate interpretation of credibility problems requires some notion of uncertainty and the potential for players to manipulate rivals' beliefs and manoeuvre them into a position which can be exploited. The scope for this would then seem to undermine the simplicity of schemes such as (3.9) for enforcing cooperation.[10]

4. Uncertainty and the Role of Private Information

In what follows, uncertainty is understood to mean asymmetric information about a rival's preferences-specifically, the domestic government's ignorance of the identity of a foreign government. The incentive to misrepresent private information under such circumstances may be seen generally from (3.4). If ω_2^{*a} is used to denote a foreign government's announcement about the value of ω_{2i}^* (i=1,2) and $x_t(\omega_2^{*a}) = E(x_t^*|\omega_2^{*a})$ is the choice of x_t conditional on this announcement, then (3.4) may be written as

$$x_{it}^*(x_t|\omega_2^{*a}) = (\omega_1^* x_t(\omega_2^{*a}) - \omega_{2i}^*)/(\omega_1^* + \omega_3^*) \quad (i=1,2) \qquad (4.1)$$

Under full information, $\omega_2^{*a} = \omega_{2i}^*$ (i=1,2) holds and the discretionary equilibrium in (3.7)-(3.8) obtains. Given some ignorance, however, there is an incentive for a foreign government to conceal information and induce a strategy $x_t(\omega_{2i}^*)$ when, in fact, ω_{2j}^* (i,j=1,2; i≠j) characterizes its preferences. In particular, by doing this, a type-2 is able to succeed in engineering a surprise exchange rate depreciation and export inflation abroad.[11] It follows that, since this incentive structure is understand by the domestic government, the choice of x_t will reflect this uncertainty. The following analysis examines this incentive structure explicitly and identifies conditions under which a credibility problem in the form of persistent ignorance exists.

4.1 Announcement Games and Incentive Compatibility

Consider first the motivation for the domestic government to pursue a strategy which is specifically designed to coerce a foreign government into revealing its true identity. This may be formalized as an 'announcement-game', a recent example of which for a closed economy model has been given by Andersen (1985). This game is in the spirit of a principal/agent-type problem where one is seeing an equilibrium which is incentive compatible in the sense that no player can profit by misrepresenting private information. The essential ingredient is the domestic government's choice of x_t conditional on an announcement ω_2^{*a} and the probability that this announcement is misleading. By virtue of the fact that $x_{it}^*(x_t|\omega_2^{*a})$ (i=1,2) in (4.1) allows some accommodation of $x_t(\omega_2^{*a})$, it is possible to envisage an appropriate choice of $x_t(\omega_2^{*a})$ which ensures a truthful revelation of preferences.

Denote by $\Omega_{it}^*(x_t, x_t^*|\omega_2^{*a})$ the payoff received by a type-i foreign government when it makes an announcement, $\omega_2^{*a} = \omega_{2j}^*$ (i,j = 1,2). From (2.6),

$$\Omega_{it}^*(x_t, x_t^*|\omega_2^{*a}) = \tfrac{1}{2}\omega_1^*[x_{it}(\omega_2^{*a}) - x_{it}^*(x_t|\omega_2^{*a})]^2$$
$$-\omega_{2i}^*[x_t(w_2^{*a}) - x_{it}^*(x_t|\omega_2^{*a})] + \tfrac{1}{2}\omega_3^*[x_{it}^*(x_t|\omega_2^{*a})]^2 \quad (i=1,2) \qquad (4.2)$$

When announcements are truthful, $\omega_2^{*a} = \omega_{2i}^*$, and when they are false, $\omega_2^{*a} = \omega_{2j}^*$ (i,j = 1,2; i≠j). A type-i player will reveal its preferences if $\Omega_{it}^*(x_t, x_t^*|\omega_{2i}^*) \leq \Omega_{it}^*(x_t, x_t^*|\omega_{2j}^*)$ and will not reveal its preferences if $\Omega_{it}^*(x_t, x_t^*|\omega_{2i}^*) \geq \Omega_{it}^*(x_t, x_t^*|\omega_{2j}^*)$ (i,j = 1,2; i≠j). Using (4.1) in (4.2), the former condition may be written as

$$[x_t(\omega_{2i}^*) - x_t(\omega_{2j}^*)][\omega_1(x_t(\omega_{21}^*) + x_t(\omega_{22}^*)) - 2\omega_{2i}^*] \leq 0 \quad (i,j = 1,2;\ i\neq j) \qquad (4.3)$$

and the decision problem facing the domestic government is to choose $x_t(\omega_{2i}^*)$ (i=1,2) which minimizes its expected disutility and ensures preference revelation. From (2.5) and letting π = prob(type-1), this can be formulated as a standard inequality-constrained optimization problem in which $x_t(\omega_{2i}^*)$ (i=1,2) is chosen to minimize

$$E\Omega_t(x_t, x_t^*|\omega_a^{*2}) = \tfrac{1}{2}\omega\{\pi[x_t(\omega_{21}^*) - x_{1t}^*(x_t|\omega_{21}^*)]^2$$
$$+ (1-\pi)[x_t(\omega_{22}^*) - x_{2t}^*(x_t|\omega_{22}^*)]^2 \qquad (4.4)$$

subject to the incentive compatibility constraints in (4.3). The technical details for solving this, which exploit complementary slackness conditions, are contained in the appendix where two types of equilibria are identified. The first is a separating equilibrium, involving the strategy $x_t(\omega_2^{*a}) = x_{it}^s$ if $\omega_2^{*a} = w_{2i}^*$ $(i=1,2)$, and ensuring that neither type of foreign government gives false information. There are two alternative separating equilibrium in this model, defined as the pair $(x_{1t}^{si}, x_{2t}^{si})$ $(i=1,2)$ such that

$$x_{1t}^{si} = [-\omega_1^*(\pi\omega_{21}^* - (1-\pi)\omega_{22}^*) + 2(1-\pi)\omega_3^*\omega_{2i}^*]/\omega_1^*\omega_3^* \quad (i=1,2) \tag{4.5}$$

$$x_{2t}^{si} = [\omega_1^*(\pi\omega_{21}^* - (1-\pi)\omega_{22}^*) + 2\pi\omega_3^*\omega_{2i}^*]/\omega_1^*\omega_3^* \quad (i=1,2) \tag{4.6}$$

$$E\Omega_t^{si} = \omega[\omega_1^*(\omega_{21}^* + \omega_{22}^*) + 2\omega_3^*\omega_{2i}^*]^2/2\omega_1^{*2}(\omega_1^* + \omega_3^*)^2 \quad (i=1,2) \tag{4.7}$$

The second type of equilibrium is a pooling equilibrium in which the domestic government plays the strategy $x_t(\omega_2^{*a}) = x_t^p$ for any ω_2^{*a} and preferences remain unidentified. In this case,

$$x_t^p = -(\pi\omega_{21}^* + (1-\pi)\omega_{22}^*)/\omega_3^* \tag{4.8}$$

$$E\Omega_t^p = \omega(\omega_{22}^* - \omega_{21}^*)^2\pi(1-\pi)/2(\omega_1^* + \omega_3^*)^2 \tag{4.9}$$

Whilst separation is feasible, therefore, the domestic government chooses pooling since $E\Omega_t^p < E\Omega_t^{si}$ $(i=1,2)$. The reason for this is the strong incentive for a type-2 foreign government to make false announcements. The domestic government has to devote so much effort to prevent this that it is simply not worth pursuing and it is optimal to offer both types of rival a 'common strategy' (i.e. the domestic government does the minimum necessary to minimize losses in the face of uncertainty). This strategy is given in (4.8) as a probability weighted average of the Nash strategies of each type of foreign government and makes players indifferent between revealing and not revealing their identity. This is in contrast with the result in Andersen

(1985) who, for a slightly different model, conjectures that whichever equilibrium dominates will depend upon the degree to which the preferences of different government types diverge.[12]

The equilibrium characteristics of variables depend upon the type of incumbent foreign government. Under a type-1, the domestic government over predicts the incentive to disinflate and sets an overly contractionary domestic policy (an exchange rate appreciation, domestic disinflation and foreign inflation) whilst an under prediction of this incentive in the case of a type-2 reverses these results. One might conjecture here that, given observation of one of these outcomes, the game thereafter will revert to the full information case. Such a conclusion, however, is premature. Since resorting to its own anti-inflationary strategy will blow the disguise of a type-2 player, there may be incentives for this player to exploit the ignorance of the domestic government and continue to masquerade as a type-1 for some time. A general appraisal of the role of private information must also consider the incentive structure motivating a foreign government to conceal or reveal its identity.

4.2 Signalling and Learning

The following analysis is motivated by the observation that prolonged uncertainty on the part of the domestic policy maker is costly for a type-1 foreign policy maker. Given this, a type-1 would presumably have an incentive to attempt to distinguish itself from an imposter as early as possible, a proposition which can be examined formally in terms of a 'signalling game' (Milgrom and Roberts, 1982b) and which has recently been addressed within the context of the closed economy by Vickers (1987).[13] In order to avoid problems of non-monotonicity, which would obscure the main insights of the analysis, it is necessary to simplify matters here by setting $\omega_1^* = 0$. This gives the dominant strategy for each type of foreign government as $x^*_{it} = \hat{x}^*_i = \tilde{x}^*_i = -\omega^*_{2i}/\omega^*_3$ with associated losses $\Omega^*_{it} = \hat{\Omega}^*_i = -\tilde{\Omega}^*_i = \omega^{*2}_{2i}/2\omega^*_3$ (i=1,2) and where $|\hat{x}^*_1| < |\hat{x}^*_2|$. In addition, this also renders separation in section 4.1 non-feasible so that the domestic government necessarily plays an unconditional pooling strategy. Finally, problems of tractability also prevent general results for T > 2 so that the analysis is conducted for a two-period game.

The focal point of strategic behaviour is in the first period, observations in which convey information about a foreign government's type which determines the outcome in the second period and the equilibrium of the game in general. The domestic government's strategy in the first period is a straightforward generalization of (4.8) for any x^*_{it} (i=1,2),

$$x_t(x^*_t) = Ex^*_t = \pi x^*_{1t} + (1-\pi)x^*_{2t} \qquad (4.10)$$

In the second period, the domestic government chooses a conditional strategy, reflecting signals emanating from the first period in the form of the observed value for x^*_t. In this second period, it is also true that a foreign government of either type will play its dominant strategy.[14]

A separating equilibrium in this game involves the strategy

$$x_{t+1}(x^*_{t+1}) = E(x^*_{t+1}|x^*_t) = \begin{cases} \hat{x}^*_1 & \text{if } x^*_t \geq x^{*s} \\ \hat{x}^*_2 & \text{if } x^*_t < x^{*s} \end{cases} \qquad (4.11)$$

where x^{*s} is determined below.[15] By playing $x^*_{1t} \geq x^{*s}$, therefore, a type-1 player has an opportunity to signal its own identity. Let $\Omega^*_{it}(x_t, x^{*s})$ be the first-period payoff incurred by a type-i foreign government when it plays $x^*_{it} = x^{*s}$ and $\Omega^*_{it+1}(\hat{x}^*_1, \hat{x}^*_i) = \Omega^*_{it+1}(x_{t+1}, \hat{x}^*_i | x^*_{it} = x^{*s})$ be the second-period payoff when it plays its dominant-strategy, having played $x^*_{it} = x^{*s}$ (i=1,2). Similarly, define $\Omega^*_{it}(x_t, \hat{x}^*_i)$ and $\Omega^*_{it+1}(\hat{x}^*_2, \hat{x}^*_i) = \Omega^*_{it+1}(x_{t+1}, \hat{x}^*_i | x^*_{it} = \hat{x}^*_i)$ as the payoffs received when a foreign government chooses its dominant strategy in both periods. The (two-period) discounted disutilities of each type of player associated with these sequences are

$$\Lambda^*_i(x_t, \hat{x}^*_1; x^{*s}, \hat{x}^*_i) = \Omega^*_{it}(x_t, x^{*s}) + \lambda\Omega^*_{it+1}(\hat{x}^*_1, \hat{x}^*_i) \quad (i=1,2) \tag{4.12}$$

$$\Lambda^*_i(x_t, \hat{x}^*_2; \hat{x}^*_i, \hat{x}^*_i) = \Omega^*_{it}(x_t, \hat{x}^*_i) + \lambda\Omega^*_{it+1}(\hat{x}^*_2, \hat{x}^*_i) \quad (i=1,2) \tag{4.13}$$

A type-1 player will choose $x^*_{1t} = x^{*s}$ if $\Lambda^*_1(x_t, \hat{x}^*_1; x^{*s}, \hat{x}^*_1) \leq \Lambda^*_1(x_t, \hat{x}^*_2; \hat{x}^*_1, \hat{x}^*_1)$ and separation will occur provided it is not profitable for a type-2 to play $x^*_{2t} = x^{*s}$ also, or $\Lambda^*_2(x_t, \hat{x}^*_1; x^{*s}, \hat{x}^*_2) \geq \Lambda^*_2(x_t, \hat{x}^*_2; \hat{x}^*_2, \hat{x}^*_2)$. Using (2.6), these conditions may be written as

$$\tfrac{1}{2}\omega^*_3(x^{*s} + \omega^*_{21}/\omega^*_3)^2 + \lambda\omega^*_{21}(\omega^*_{21} - \omega^*_{22})/\omega^*_3 \leq 0 \tag{4.14}$$

$$\tfrac{1}{2}\omega^*_3(x^{*s} + \omega^*_{22}/\omega^*_3)^2 + \lambda\omega^*_{22}(\omega^*_{21} - \omega^*_{22})/\omega^*_3 \geq 0 \tag{4.15}$$

The precise characterization of a separating equilibrium now follows by considering the strategies x_1^{*s} and x_2^{*s} obtained from the equality conditions in (4.14)-(4.15) respectively. Since the dominant strategy of a type-1 player is $\hat{x}^*_1$ and $\hat{x}^*_1 < x^{*s}_2 < x^{*s}_1$, this player chooses $x^*_{1t} = x^{*s}_2$ where

$$x^{*s}_2 = \{1 - \surd[2\lambda(\omega^*-1)/\omega^*]\}\hat{x}^*_2 \tag{4.16}$$

with $\omega^* = \omega^*_{22}/\omega^*_{21}$. The type-2 player than chooses its dominant strategy and the separating equilibrium is described by

$$x^*_{1t} = x^{*s}_2,\ x^*_{2t} = \hat{x}^*_2;\ x^*_{it+1} = \hat{x}^*_i \qquad (i=1,2) \tag{4.17}$$

$$x_t = \pi x^{*s}_2 + (1-\pi)\hat{x}^*_2;\quad x_{t+1} = \begin{cases} \hat{x}^*_1 & \text{if } x^*_t \geq x^{*s}_2 \\ \hat{x}^*_2 & \text{if } x^*_t < x^{*s}_2 \end{cases} \tag{4.18}$$

$$\Lambda^{*s}_1 = (1-\pi)\omega^*_{21}(x^{*s}_2 - \hat{x}^*_2) + \tfrac{1}{2}\omega^*_3 x^{*s2}_2 + \tfrac{1}{2}\lambda\omega^*_3\hat{x}^{*2}_1 \tag{4.19}$$

$$\Lambda^{*s}_2 = \pi\omega^*_{22}(\hat{x}^*_2 - x^{*s}_2) + \tfrac{1}{2}(1+\lambda)\omega^*_3\hat{x}^{*2}_2 \tag{4.20}$$

Hence, if the foreign government is of type-1, the equilibrium involves a first-period exchange rate appreciation, domestic disinflation and output contractions and, for a type-2, an exchange rate depreciation with similar behaviour in foreign variables. Full information is ensured thereafter.

In contrast to this, a pooling equilibrium involves the strategy

$$x_{t+1}(x^*_{t+1}) = E(x^*_{t+1}|x^*_t) = \begin{cases} \pi\hat{x}^*_1 + (1-\pi)\hat{x}^*_2 & \text{if } x^*_t \geq x^{*p} \\ \hat{x}^*_2 & \text{if } x^*_t < x^{*p} \end{cases} \tag{4.21}$$

for some x^{*p}. Defining $\Omega^*_{it}(x_t, x^{*p})$ and $\Omega^*_{it+1}(\hat{x}, \hat{x}^*_i) = \Omega^*_{it+1}(x_{t+1}, \hat{x}^*_i | x^*_{it} = x^{*p})$, where $\hat{x} = \pi\hat{x}^*_1 + (1-\pi)\hat{x}^*_2$, as the per-period payoffs associated with a type-i player choosing $x^*_{it} = x^{*p}$ (i=1,2),

$$\Lambda^*_i(x_t, \hat{x}; x^{*p}, \hat{x}^*_i) = \Omega^*_{it}(x_t, x^{*p}) + \lambda\Omega^*_{it+1}(\hat{x}, \hat{x}^*_i) \qquad (i=1,2) \qquad (4.22)$$

Pooling occurs if both types of players find it optimal to play $x^*_{it} = x^{*p}$ or $\Lambda^*_i(x_t, \hat{x}; x^{*p}, \hat{x}^*_i) \leq \Lambda^*_i(x_t, \hat{x}^*_2; \hat{x}^*_i, \hat{x}^*_i)$ (i=1,2) which gives

$$\tfrac{1}{2}\omega^*_3(x^{*p} + \omega^*_{2i}/\omega^*_3)^2 + \lambda\pi\omega^*_{2i}(\omega^*_{21} - \omega^*_{22})/\omega^*_3 \leq 0 \qquad (i=1,2) \qquad (4.23)$$

Proceeding as before, it is possible to define a pooling equilibrium as

$$x^*_{it} = x^{*p}; \qquad x^*_{it+1} = \hat{x}^*_i \qquad (i=1,2) \qquad (4.24)$$

$$x_t = x^{*p}; \qquad x_{t+1} = \begin{cases} \pi\hat{x}^*_1 + (1-\pi)\hat{x}^*_2 \text{ if } x^*_t \geq x^{*p} \\ \hat{x}^*_2 \text{ if } x^*_t < x^{*p} \end{cases} \qquad (4.25)$$

$$\Lambda^{*p}_1 = \lambda(1-\pi)\omega^*_{21}(\hat{x}^*_1 - \hat{x}^*_2) + \tfrac{1}{2}\omega^*_3 x^{*p2} + \tfrac{1}{2}\lambda\omega^*_3\hat{x}^{*2}_1 \qquad (4.26)$$

$$\Lambda^{*p}_2 = \lambda\pi\omega^*_{22}(\hat{x}^*_2 - \hat{x}^*_1) + \tfrac{1}{2}\omega^*_3 x^{*p2} + \tfrac{1}{2}\lambda\omega^*_3\hat{x}^{*2}_2 \qquad (4.27)$$

In general, whichever of the above equilibria dominate will depend upon the extent to which the preferences of different government types diverge and, in particular, separation is more likely for relatively similar government types. The reason for this is that a greater divergence between preferences implies greater potential gains for a type-2 player if it is able to successfully mislead the domestic government into believing it is of type-1. Given this, it is more difficult for the type-1 player to select a x^{*s} which the type-2 has no incentive to play.[16] This idea can be used to motivate the general characterization of prolonged uncertainty in which the domestic government employs optimal (Bayesian) learning rules to update its beliefs about the identity of an incumbent rival on the basis of observations of x^*_t.

Following Driffill (1986), consider a sufficienty low value for ω^*_{21} for which $x^{*s}_2 > 0$ so that successful identification requires a type-1 player to actually follow an expansionary policy. In conjunction with $x^{*p} = 0$ which reduces the loss associated with pooling in (4.26), $\Lambda^{*s}_1 > \Lambda^{*p}_1$ and the type-1 player chooses $x^*_{1t} = x^{*p} = 0$. The choice for a type-2 is whether to play $x^*_{2t} = 0$ as well or $x^*_{2t} = \hat{x}^*_2$. The generalization of the game involves a time-dependent π such that $\pi_t = \text{prob}(\text{type-1}|x^*_{t-1} = 0)$ and $1-\pi_t = \text{prob}(\text{type-2}|x^*_{t-1} = 0)$ and defining $\theta_t = \text{prob}(x^*_t = 0|\text{type-2})$ and $1-\theta_t = \text{prob}(x^*_{2t} = \hat{x}^*_2|\text{type-2})$. This probability, θ_t, is a choice variable of a type-2 foreign government and μ_t is used to denote the domestic government's perception of θ_t. Then $\text{prob}(x^*_t = 0) = \pi_t + (1-\pi_t)\mu_t$ and π_t is revised according to Bayes' rule,

$$\pi_{t+1} = \pi_t/(\pi_t + (1-\pi_t)\mu_t) \tag{4.28}$$

The domestic government's strategy in the first period is a generalization of (4.10), $x_t(x_t^*) = Ex_t^* = prob(x_t^* = 0).0 \quad + prob(x_t^* = \hat{x}_2^*)\hat{x}_2^*$ or

$$x_t(x_t^*) = Ex_t^* = x_t(\pi_t, \mu_t) = (1-\pi_t)(1-\mu_t)\hat{x}_2^* \tag{4.29}$$

and in the second period,

$$x_{t+1}(x_{t+1}^*) = E(x_{t+1}^* | x_t^*) = \begin{cases} \pi_{t+1}\hat{x}_1^* + (1-\pi_{t+1})\hat{x}_2^* \text{ if } x_t^* = 0 \\ \hat{x}_2^* \text{ if } x_t^* < 0 \end{cases} \tag{4.30}$$

Hence, with probability θ_t a type-2 chooses $x_{2t}^* = 0$ and receives the current payoff, $\Omega_{2t}^*(x_t, 0) = \Omega_{2t}^*(\pi_t, \mu_t | x_{2t}^* = 0)$; in addition, π_t is revised according to (4.28) and $\Omega_{2t+1}^*(x_{t+1}, \hat{x}_2^*) = \Omega_{2t+1}^*(\pi_{t+1} | x_{2t}^* = 0)$ is collected subsequently. Conversely, with prob $1-\theta_t$, $x_{2t}^* = \hat{x}_2^*$ and a type-2 blows its disguise, giving the payoffs $\Omega_{2t}^*(x_t, \hat{x}_2^*) = \Omega_{2t}^*(\pi_t, \mu_t | x_{2t}^* = \hat{x}_2^*)$ and $\Omega_{2t+1}^*(\hat{x}_2^*, \hat{x}_2^*) = \Omega_{2t+1}^*(\pi_{t+1} | x_{2t}^* = \hat{x}_2^*)$ (in particular, $\pi_{t+1} = 0$). This contains the seeds of the repeated game with imperfect information developed by Kreps and Wilson (1982b) and Milgrom and Roberts (1982a), recent applications of which to closed economy models can be found in Barro (1986) and Backus and Driffill (1985a).[17]

For the case in which $\omega_{21}^* = 0$ (so that only a type-2 foreign government has a preference for lower foreign inflation), Blackburn (1987b) has described the evolution of a T > 2 period game as follows. For some period at the start of the game, a sufficiently good reputation induces a type-2 player to set $\theta_t = 1$ (i.e., play $x^*_{2t} = 0$ with certainty), mimicing the cooperative equilibrium.[18] For some period after this, the type-2 player is indifferent between masquerading as a type-1 and resorting to its dominant strategy. This is a period of randomization in which $0 < \theta_t < 1$ and the domestic government pursues a contactionary monetary policy leading to an exchange rate appreciation and a domestic recession.[19] Finally, at some point, a type-2 resorts to its dominant strategy, setting $\theta_t = 0$ (i.e., playing $x^*_{2t} = \hat{x}^*_2$ with certainty), in which case reputation is blown and the equilibrium thereafter degenerates to the discretionary equilibrium in the one shot full information game.

5. Concluding Remarks: Conflict, Cooperation and Coordination

The paper has been concerned to show how conflicting objectives and informational asymmetries between national policy makers may interact to generate different types of equilibria which describe the behaviour of important macroeconomic variables in a world of interdependent economies. Emphasis has been placed upon problems of non-coordinated policy design and incomplete information arising from non-cooperative behaviour and the design of strategies as a response to these problems in a framework which elicits the precise incentive structure motivating players to conceal or misrepresent private information. This section concludes the analysis by returning to a theme identified in the introduction on the implications for international cooperation and policy coordination.

It has been shown here and elsewhere that cooperative policy making can be sustained in a non-cooperative environment by entertaining the notions of reputation and threat strategies. These threats may take the form of fairly simple 'tit-for-tat' strategies such as (3.9) and, to this extent, offer reassurance to those who are sympathetic to the idea of international cooperation. The central issue which is being addressed here is one of policy coordination but it is possible to argue that the question of cooperation is much broader than this and policy coordination just one aspect. In a world characterized by uncertainty and idiosyncracies in the information structure, the problem of resolving conflict takes on new dimensions. This has been the focus of attention in the foregoing analysis which stressed the crucial role of the information structure in determining the outcome of a game and the incentive for players to disguise their intentions by concealing or misrepresenting private information. This analysis, which may also be seen as drawing together other independent research into a single general paradigm, identified conditions under which private information is never revealed. Provided that countries cannot design suitable incentive schemes for coercing rivals into divulging information and provided that these rivals cannot themselves signal this information, a pooling equilibrium characterizes the world economy in which imposters sustain a level of deception in order to reap the benefits of ignorance at some later date.

The implications of this for international cooperation are important but have hitherto been eschewed in discussions of international policy design. Put simply, without knowledge of the identity of potential members in an agreement, it is difficult to envisage a successful cooperative solution. More generally, for any type of asymmetry in the information structure (whether it arises from asymmetric information about the characteristics of rivals or economy-specific information about the nature and source of exogenous shocks in a stochastic world), the trust required for a cooperative strategy in the form of a truthful revelation of private information must be seen as a pre-requisite for cooperative policy design. This, in turn, motivates a two-stage process for enforcing cooperation: first, an assurance about the integrity of potential members, the analysis in section 4 indicating how this might be achieved; and second, having obtained this assurance and in the absence of a formal institutional structure for enforcing and policing commitments, the design of penalty schemes for punishing a known type of rival if it defects from the cooperative policy. These two aspects may yield policy behaviour which is quite different from that implied by more orthodox approaches which ignore the information dimensions of the problem.

In summary, a complete evaluation of the issue of international policy design in a strategic environment must appreciate problems of both non-coordinated policy making and informational asymmetries arising from non-cooperative behaviour and the dual role of cooperation in terms of policy coordination and information coordination.

Appendix

This appendix derives the equilibria for the announcement game in section 4.1. From (4.1),

$$x_t(\omega^*_{2i})-x^*_{it}(x_t|\omega^*_{2i}) = [\omega^*_3 x_t(\omega^*_{2i}) + \omega^*_{2i}]/(\omega^*_1 + \omega^*_3) \quad (i=1,2) \tag{A.1}$$

so that substituting (A.1) into (4.4), the optimization problem-minimizing (4.4) with respect to $x_t(\omega^*_{2i})$ $(i=1,2)$ subject to (4.3)--can be formulated in terms of the Lagrangian,

$$\begin{aligned} L(x_t(\omega^*_{21}),\ x_t(\omega^*_{22})) = {} & \omega\{\pi(\omega^*_3 x_t(\omega^*_{21}) + \omega^*_{21})^2 \\ & + (1-\pi)(\omega^*_3 x_t(\omega^*_{22}) + \omega^*_{22})^2\}/2(\omega^*_1 + \omega^*_3) \\ & + \psi_1[x_t(\omega^*_{21})-x_t(\omega^*_{22})][\omega^*_1(x_t(\omega^*_{21})+x_t(\omega^*_{22}))-2\omega^*_{21}] \\ & + \psi_2[x_t(\omega^*_{22})-x_t(\omega^*_{21})][\omega^*_1(x_t(\omega^*_{21})+x_t(\omega^*_{22}))-2\omega^*_{22}] \end{aligned} \tag{A.2}$$

which gives the first-order conditions

$$\begin{aligned} & \omega\pi(\omega^*_3 x_t(\omega^*_{21})+\omega^*_{21})\omega^*_3/(\omega^*_1+\omega^*_3)^2 + 2\psi_1[\omega^*_1 x_t(\omega^*_{21})-\omega^*_{21}] \\ & \quad - 2\psi_2[\omega^*_1 x_t(\omega^*_{21})-\omega^*_{22}] = 0 \end{aligned} \tag{A.3}$$

$$\begin{aligned} & \omega(1-\pi)(\omega^*_3 x_t(\omega^*_{22})+\omega^*_{22})\omega^*_3/(\omega^*_1+\omega^*_3)^2 - 2\psi_1[\omega^*_1 x_t(\omega^*_{22})-\omega^*_{21}] \\ & \quad + 2\psi_2[\omega^*_1 x_t(\omega^*_{22})-\omega^*_{22}] = 0 \end{aligned} \tag{A.4}$$

$$\psi_1[x_t(\omega^*_{21})-x_t(\omega^*_{22})][\omega^*_1(x_t(\omega^*_{21})+x_t(\omega^*_{22}))-2\omega^*_{21}] = 0 \tag{A.5}$$

$$\psi_2[x_t(\omega^*_{22})-x_t(\omega^*_{21})][\omega^*_1(x_t(\omega^*_{21}) + x_t(\omega^*_{22}))-2\omega^*_{22}] = 0 \tag{A.6}$$

and there are four cases to be considered: (a) $\psi_1 = \psi_2 = 0$; (b) $\psi_2 > 0$, $\psi_1 = 0$; (c) $\psi_2 = 0$, $\psi_1 > 0$; (d) $\psi_1, \psi_2 > 0$. The feasibility of these proposed solutions can be investigated using the complementary slackness conditions obtained from (A.5)-(A.6) in conjunction with (4.3).

(a) $\psi_1 = \psi_2 = 0$: In this, the full information solution obtains with $x_t(\omega^*_{2i}) = -\omega^*_{2i}/\omega^*_3$ (i=1,2). But whilst the inequality in (4.3) is satisfied for i=1, it is violated for i=2 so that this is not a feasible solution.

(b) $\psi_2 > 0$, $\psi_1 = 0$: These conditions imply the expressions in (4.5)-(4.6) for i=1. The solution must satisfy the strict inequality in (4.3) for i=2, the condition for which is $\pi > (\omega^*_1\omega^*_{22}-\omega^*_3\omega^*_{21})/(\omega^*_1(\omega^*_{21}+\omega^*_{22}) + 2\omega^*_3\omega^*_{21})$. Substituting the solution into (4.4) using (A.1) gives the loss in (4.7) for i=1.

(c) $\psi_1 > 0$, $\psi_2 = 0$: These conditions give the expressions in (4.5)-(4.6) for i=2 which must satisfy the strict inequality in (4.3) for i=1, the condition for which is $\pi > \omega^*_{22}(\omega^*_1+\omega^*_3)/(\omega^*_1(\omega^*_{21}+\omega^*_{22})+2\omega^*_{22}\omega^*_3)$. Substituting the solution into (4.4) using (A.1) gives the loss in (4.7) for i=2.

(d) $\psi_1, \psi_2 > 0$: In this case, the solution is given by (4.8) with associated loss in (4.9).

Footnotes

1. See Hamada (1974, 1976, 1979) for the seminal contributions in this area and McMillan (1986) for a survey of game theory in international trade. For a general review of game theory in macroeconomic policy design, including the issues which are raised below, see Blackburn (1987a) and Blackburn and Christensen (1987).

2. On the latter point, see also Rogoff (1986) for an investigation using a simpler, analytical model.

3. See also Blackburn and Christensen (1986), Horn and Perrson (1985), Rogoff (1985) and Tabellini (1985). This literature draws on themes developed by Friedman (1971), Kreps and Wilson (1982a,b) and Milgrom and Roberts (1982a,b).

4. One way of avoiding this problem has been to model the game between a government and a large trade union (Blackburn and Christensen, 1986; Horn and Perrson, 1985; Tabellini, 1985).

5. The case of extrinsic uncertainty arising from contemparaneously unobservable stochastic disturbances is examined in Blackburn (1987b) using a similar model. In the context of the closed economy, this issue has been addressed by Andersen (1986), Canzoneri (1985) and Cukierman and Meltzer (1986).

6. The time horizon is assumed to be finite or infinite depending upon the structure of the game.

7. The underlying structure is essentially a flexible price two country Mundell-Fleming model in which private sector expectations are formed regressively. Hence, if x and x^* were interest rates (measured negatively), the parameter γ would be the degree of regressivity in expectations.

8. For simplicity it is assumed that all players possess the same rate of discount. This also rules out potential conflict arising from different players' subjective views about the importance of the future.

9. The infinite horizon assumption is used in order to avoid the 'chain-store paradox' (Selten, 1975).

10. The scheme in (3.9) is an example of the more general 'rule-of-thumb' by which players treat rivals in a way which they themselves would like to be treated in the future and punish rivals for disobedience in a likewise manner. Another criticism of the approach taken here and elsewhere centres on the symmetry assumption and the idea that the successfulness of strategies such as (3.9) rely on the fact that countries are treated identically, neither country commanding a dominant position in world trade or international capital movements. It is possible to argue, however, that for actual economies which differ in size and importance, the credibility of threats is seriously undermined because either the punishment is simply not strong enough or there is a fear of retaliation on a much larger scale.

11. Recall that $\omega_{21}^{*} < \omega_{22}^{*}$ so that announcing ω_{21}^{*} induces an overly expansionary domestic monetary policy.

12. On a slightly different note, one might envisage the possibility that, under some circumstances when separation dominates, merely the threat of playing $x_t(\omega_2^{*a}) = x_{it}^{s}$ if $\omega_2^{*a} = \omega_{2i}^{*}$ $(i=1,2)$ will be sufficient to enforce information revelation. In the current model, however, this threat is not credible, since the pooling strategy will always be played in preference to separation.

13. Driffill (1986) generalizes the analysis in Vickers (1987) and is returned to below.

14. Note, therefore, that for the specific case in which the foreign government chooses its dominant strategy always, the expression in (4.10) reduces to (4.8).

15. As before, since there are only two types of foreign government, this step function is a valid characterization of optimizing strategies.

16. This is a general qualification of the argument in Vickers (1987) which suggests that it is always possible to rule out pooling on the grounds that it is always possible for a type-1 player to choose a sufficiently high value for x^{*s} (i.e., a sufficiently expansionary policy) which a type-2 player would never find advantageous to play. As stated in the text, the general rule is that the outcome will depend upon the degree to which foreign government types differ.

17. See also Blackburn and Christensen (1986), Horn and Perrson (1985) and Tabellini (1986). Generalizations to two-sided uncertainty can be found in Backus and Driffil (1985b). Driffil (1986) has also shown the superiority of a pooling equilibrium in pure strategies.

18. For any given stock of reputation, this outcome is more likely and persists longer as the rate of discount falls or the time horizon increases, both of which impose greater penalties for bad behaviour.

19. During this period, reputation is increasing in λ, reflecting the fact that a lower rate of discount makes a type-2 more resistant to an exchange rate depreciation so that observation of $x_t^* = 0$ is weaker verification of a type-1. In addition, whilst π_t rises over time, μ_t falls because of the temptation to forego further investment in good will.

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