# "WHY THE EMS? Dynamic Games and the Equilibrium Policy Regime"

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A B S T R A C T

Assuming that full coordination of monetary policies is too complex to set up, we ask whether an EMS may be Pareto-superior to a flexible exchange rate regime. The case under consideration is one where two countries inherit excessive, but different, inflationary conditions. We show that an EMS is not a fully coordinated system so that there is a residual game played within the EMS. It appears plausible that a non-cooperative (Nash) solution within the EMS dominates a free-float non-cooperative solution. We allow for realignments and analyse their optimal timing. We also study how capital controls interfere with both regimes.

# WHY THE EMS?

## Dynamic Games and the Equilibrium Policy Regime

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## 1. INTRODUCTION

Given a complete specification of a policy maker's preferences (her objective function) and of the economic structure which constrains the choice of policy variables, it is conceptually straightforward to compute the optimal policy. Within such a framework, the notion of a policy regime has little meaning. The dependence of the optimal policy on the specification of the objective function and on the economic structure is essentially continuous: small changes in preferences or constraints will typically lead to small changes in the rules which govern optimal policies.

In contrast, the notion of a policy regime suggests discretely different policy rules. To adopt a policy regime is to place an additional set of constraints on the form of the policy rule. Why might the imposition of additional constraints lead to an outcome that yields the policy maker a higher expected utility? As a matter of logic, at least three explanations can be advanced. First, the additional constraints may embody some kind of precommitment. Second, they may reflect cooperation, as when one policy maker otherwise neglects externalities imposed on other policy makers. Third, they may arise from bounded rationality. Bounded rationality is discussed in the papers by Rubinstein and Fershtman in this volume. Broadly speaking, we take bounded rationality to mean that costs arise either in the computation of optimal policies by the policy maker or in the monitoring of such policies by the private agents (whose behaviour is described by the economic structure). Rather than make these costs fully explicit in the model, a convenient simplification is to impose on the optimisation problem the additional constraint that policy be sufficiently simple in some appropriate sense. Some authors[1] have gone so far as to argue that policy rules themselves should therefore be very simple. We consider that this requirement is unduly restrictive. An intermediate position, which forms the basis of our analysis, is to argue that policy makers must choose between a limited number of clearly different policy regimes. Each regime has some aspects of policy which are simple, visible, and easily monitored. Typically, however, each policy regime will leave the policy maker with some degrees of freedom, and the optimal

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1. Lucas (1980), Currie and Levine (1984).

rules for the policy variables which can be freely chosen within a particular regime may be quite complex. It is for this reason that the concept of a policy regime offers an intermediate and interesting compromise between pure simplicity and full complexity.

Examples of policy regimes include the choice between a money stock policy and an interest rate policy, the choice between fixed and floating exchange rates, and the choice between tariffs and import quotas. In this paper, it is the nature of the exchange rate regime which is our chief concern.

For a single country, the analysis of exchange rate regime has typically focussed on two issues. The first is essentially deterministic and concerns the role of financial discipline. Whereas fixed nominal exchange rates provide a nominal anchor, floating exchange rates can in principle accommodate any level of domestic inflation. A credible anti-inflation policy requires that the nominal anchor be provided elsewhere in the economy, as in the appointment of a conservative central banker. The second is essentially stochastic and focuses on the ability of different exchange rate regimes to protect the domestic economy from random disturbances. In the spirit of Poole's (1970) seminal paper on the choice of a domestic monetary regime, this literature has not led to any clear answer. The optimal exchange rate regime depends sensitively on the variance covariance matrix of the possible disturbances in various markets, both domestic and external.

Whereas early analyses considered one country in isolation, the recent revival of work on policy coordination emphasises interdependence of national policy decisions[2]. Here the notion of policy regimes is especially useful. In the real world, if countries are to cooperate it seems literally incredible that practical coordination could refer to hugely sophisticated policy design. Each country must be able to understand and monitor the policies of others, and agreement about policy regimes may offer the only feasible vehicle for such cooperation. Work along this line has recently emerged as part of an effort to analyse the functioning of the EMS. Most of the literature along these lines,

2. See, among others, Cooper (1984), Hamada (1976), Sachs (1983), Oudiz and Sachs (1984), Canzoneri and Gray (1984), Canzoneri and Henderson (1985).

however, has focused on how an EMS-type arrangement can optimally work.[3] This line of research, however, faces three important difficulties.

The first one is the familiar (n-1) problem. As is well known, when n countries enter a fixed exchange rate arrangement, this puts a constraint on n-1 parities only. Deciding on how to allocate the remaining degree of freedom - the aggregate level of their money stock - is an unresolved issue. When applied to the EMS, it is often postulated that one country, namely Germany, captures this degree of freedom and assumes de-facto leadership. This is the view developed by Giavazzi and Giovannini (1987) and Giavazzi and Pagano (1986). Yet, it runs counter to the formal setting of the EMS which did not specify that one currency would assume a central role, pushing the others to the periphery, so that an explanation ought to be given as to why it might have evolved that way. One rationale is that all countries benefit from Germany's credibility in the area of monetary policy. Following on Rogoff's (1985) important intuition that countries may wish to have a central bank more conservative than the public, in order to deter the inflationary bias which emerges when pre-commitment is impossible (see Barro and Gordon (1983)), this view concludes that Germany acts as the EMS conservative central bank. If each country is willing to join this arrangement, why does it not also have the political will to appoint its own central banker? This is unexplained. Moreover, if countries enter the EMS with different initial conditions, one country's central banker may be too conservative, or insufficiently conservative, for another country. It is unclear why international institutional design is preferred to domestic ones: surely France or Italy could appoint optimally conservative bankers, and find institutional ways to pre-commit themselves rather than entering the EMS.

A second shortcoming of the existing literature, and one which extends beyond work on the EMS, is to envision a fixed exchange rate regime as one where parities are fixed once and for all. That is not the way these regimes function. Both the Bretton-Woods system and the EMS allowed for realignments and margins of fluctuation. This does not represent a minor qualification, for it allows for significantly more freedom than a rigidly fixed system. Not only

3. See Giavazzi and Giovannini in this volume, Melitz and Michel (1985).

does it allow for short-term independence (i.e. as long as the margin is not exhausted), it also permits permanently different steady state inflation rates. Long-run convergence, and the short-run constraints associated with the need to achieve it, is not an implication of adjustable exchange rate regimes. Any failure to recognise these features is likely to severely distort the analysis.

Finally we remarked earlier that the choice of a regime cannot be separated logically from the design of policy interdependence, or from its failure to occur.[4] To put things differently, in the case of the EMS, it must be shown that member countries have good reasons to belong to the system <u>and</u> adopt a set of interdependent policies rather than staying out of it <u>and</u> possibly adopting a different set of policies. To be more precise, conditional on the adoption of a particular cooperative regime (a set of EMS rules), non cooperative bargaining then determines the setting of the remaining policy variables within the degrees of freedom that regime allows. Foreseeing how each possible cooperative regime is likely to evolve, the equilibrium regime is the regime which all member countries wish to join.

Our purpose, in this paper, is to take a step in the direction of analysing jointly the choice of an exchange rate regime and of macroeconomic policies. We ask whether countries will ever enter into an EMS, with the implied choice of policies, given that they have the option of floating, with a different set of implied policies. This research program raises a number of difficulties.

First, we only consider two countries. This is solely for technical reasons. As will appear quickly, the modelling of policy interdependence in a two-country dynamic framework is quite involved, and rules out, for the time being, models with a larger number of countries. This is a serious limitation as n-country games are known not to be mere extensions of two-country games. Indeed the whole range of strategic interactions is modified when coalitions become possible.

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4. Note that we do not presume full coordination. We consider the whole range of policy combinations, ranging from full coordination to Nash solutions including, possibly, bargaining or Stackelberg leadership.

Second, we would have to consider the various forms of policy interactions, considering such dimensions as coordination or not, open or closed-loop, simple rules versus bargaining, etc... Based on casual empiricism, we simply describe the free floating regime as the outcome of a non-cooperative Nash game. We then ask whether there exist regimes (EMS, capital controls) which Pareto-dominate the free-float, i.e. whether in some version these regimes belong to the core of the bargain which takes as its start the free float regime. We then discuss whether it is possible to further narrow down the characteristics of the equilibrium regime likely to be chosen.

Third, we wish to introduce the important possibility of realignment. This is done by considering a three period game, where nominal exchange rate changes are sometimes possible, i.e. either at the end of the first or of the second periods. The benchmark flexible regime is the special case when realignments are possible at the end of both periods.

Fourth, the game has to be, and is, dynamic. This raises the now familiar issues of time-inconsistency and credibility. We regard these issues as important. Yet our particular model is designed to avoid them altogether, for the sake of simplicity. It will be important to analyse, in subsequent work, the implications for our results of this limitation.

Although precommitment may provide a rationale for cooperation (see e.g. Giavazzi and Pagano), in this paper we focus on coordination issues emerging solely because the two countries are linked by externalities through the exchange rate. If they are identical in all respects (structure, size, initial conditions and objectives), then whether they coordinate or play Nash, the exchange rate remains unaffected (see e.g. Sachs (1983)). In order to raise interesting exchange rate regime issues, therefore, some asymmetry is needed. In this paper, we consider the case where the two countries only differ by their initial conditions. Allowing for differences in structure and objectives is left for further research.

Finally, one important aspect of EMS history is the existence of capital controls. By modifying the channel of interdependence, capital controls are likely to affect the costs and benefits of EMS membership. We consider this issue at the end of the paper.

In the next section, we present the model and its steady state. The free-float, reference, regime is described in Section 3. Section 4 presents two versions of the EMS regime and shows under what condition either version is likely to be the equilibrium regime. Capital controls are analysed in Section 5 for the free floating case, and in Section 6 within the EMS regime.

## 2. THE MODEL

We consider two interdependent economies. Each of them has an intertemporal welfare function defined on the path of its own output and rate of inflation. Domestic price sluggishness is introduced through core inflation which changes only slowly. [5,6] The channels of interdependence are trade, which affects aggregate demand for goods and aggregate price levels, and financial markets in which, in the absence of capital controls, each country's assets are perfect substitutes.

The model is specified in discrete time. An important simplification is achieved by limiting its dynamics to two periods, one and two. Period zero is the past, and describes the situation as the two countries contemplate the possibility of joining an EMS, and/or of adopting capital controls. At the end of period zero, both countries inherit inflationary conditions, although each to a different degree. Period three is the steady state, defined as zero inflation and zero deviation from equilibrium output. Thus, both countries have two periods to converge to their steady state, and the question we ask is

5. Price stickiness is an important empirical regularity. In a recent paper, Mussa (1986) notes forcefully that this regularity invalidates "nominal exchange regime neutrality", i.e. the property that real exchange rates behave similarly under flexible and fixed nominal exchange rates. Acknowledging this point is therefore essential in any analysis of exchange rate regime choice.

6. We use the Buiter and Miller (1982) approach to modelling price sluggishness. Alternatively, it can be done via multiperiod wage contracts as in Fischer (1977), Taylor (1980), and Canzoneri and Henderson (1986).

which regime allows them to do that most efficiently.[7]

For simplicity of exposition, we call one country France, the other one Germany; German variables are denoted by a star superscript (*), French variables are unstarred. The two countries are perfectly identical, except that France inherits a higher rate of core inflation than Germany. Let q denote the real exchange rate between France and Germany. A rise in q makes France more competitive; it is a real depreciation of the Franc against the DM. Measuring q in logarithms and letting r denote the real interest rate, perfect capital mobility implies

$$q_{+1} - q = r - r^{*} = \bar{r} \tag{1}$$

where we use the notation (+) to denote the sum of French and German variables and the superscript (-) to denote the French variable minus its German equivalent.

Output y depends on competitiveness, and on real interest rates at home and abroad, the latter because it affects foreign demand and hence domestic exports. Letting all parameters be positive,

$$y = aq - br - b\theta r^{*} \qquad\qquad y^{*} = -aq - br^{*} - b\theta r \tag{2}$$

where the positive fraction θ reflects the degree of interdependence of the two countries' goods markets.[8]

7. There is no particular restriction involved in forcing convergence to a well-defined steady-state: this is inded a feature common to all dynamic models, unless there exist multiple equilibria. The restriction that this be done in two periods is not particularly strong if it simply collapses a richer dynamic structure. A more serious restriction is that our set-up rules out balance of payments crises. Such crises are better modelled in continuous time. Finally, we force long run convergence of monetary policies (to a zero inflation rate). This, we noted earlier, may be a limitation of the analysis. Its treatment would require repeated games.

8. These equations can be derived from standard IS equations such as $y = \alpha q - \beta r + \theta y^{*}$ and $y^{*} = -\alpha q - \beta r^{*} + \theta y$. Note that the sign of b in (2) is ambiguous in more elaborate models. For a discussion see Sachs (1986).

Next we describe wage-price dynamics. Letting $\pi$ denote the inflation rate and p the domestic price level (the price of domestic goods) in logarithms

$$\pi = p-p_{-1} + \theta(q-q_{-1}) \qquad \pi^* = p^*-p^*_{-1} - \theta(q-q_{-1}) \tag{3}$$

Each country's inflation rate depends on the change in the price of its domestic goods plus the extra contribution from import prices when the real exchange rate changes.

Each country has a core inflation rate x which adjusts slowly to actual inflation

$$x-x_{-1} = d(\pi-x_{-1}) \qquad x^*-x^*_{-1} = d(\pi^*-x^*_{-1}) \tag{4}$$

with $d < 1$, and has an expectations-augmented Phillips curve which makes domestic prices respond to deviations of domestic output y from its (constant) level of petential output, and to the inherited level of core inflation

$$p-p_{-1} = cy + x_{-1} \qquad p^*-p^*_{-1} = cy^* + x^*_{-1} \tag{5}$$

Together, equations (3)-(5) yield

$$x-x_{-1} = fy + g(q-q_{-1}) \qquad x^*-x^*_{-1} = fy^* - g(q-q_{-1}) \qquad \begin{array}{l} f=dc \\ g=d\theta \end{array} \tag{6}$$

It will be convenient to introduce the variable z defined as:

$$z = z_{-1} + y \qquad z^* = z^*_{-1} + y^* \tag{7}$$

This variable is the sum of the entire past history of output deviations from potential. In what follows, z will be the state variable, describing the inherited state of the economy. With (7), (6) can be rewritten as:

$$x = fz + gq \qquad x^* = fz^* - gq \tag{6'}$$

where we have used the initial conditions[9] on z and $z^*$:

$$z_o = (x_o - gq_o)/f \qquad\qquad z^*_o = (x^*_o + gq_o)/f$$

These initial conditions will provide the only source of assymmetry between France and Germany. We will assume:

$$z_o > z^*_o > 0$$

Both countries inherit an over expansionary past, France more so than Germany. This initial condition can be fully interpreted using (6′). First, it implies that $\overset{+}{x}_0 = f\overset{+}{z}_0$ the average core inflation of both countries, is positive, i.e. we start in an inflationary world. Second, $\bar{z}_0 = f\bar{x}_0 - 2gq_0 > 0$ means that France's worse situation is the result of either higher core inflation $(\bar{x}_0 > 0)$ or an overvalued real exchange rate ($q_0 > 0$, where equilibrium corresponds to $q_0 = 0$), or a combination of both.

The model is completed by a description of preferences. These are defined on y, the deviation of output from potential, and on x, the rate of core or underlying inflation. Since the structure is linear, little of substance would be altered by letting preferences depend on actual inflation π rather than on core inflation x; the algebra would be however more tedious. Letting L denote the present value of the cost of deviations from target, we assume

$$\begin{aligned}
L &= y_1^2 + y_2^2 + v(x_1^2 + x_2^2) && \text{if } y_3 = x_3 = 0 \\
&= \infty && \text{if } y_3 \neq 0 \text{ or } x_3 \neq 0 \\
L^* &= y_{1*}^2 + y_{2*}^2 + v(x_{1*}^2 + x_{2*}^2) && \text{if } y_{3*} = x_{3*} = 0 \\
&= \infty && \text{if } y_{3*} \neq 0 \text{ or } x_{3*} \neq 0
\end{aligned} \tag{8}$$

Thus policy makers have zero targets for y and x, and v is the relative weight of inflation deviations relative to output deviations. For simplicity the

9. The initial condition is nothing else than a choice of the constant of integration such that (6′) holds in any period, e.g. in period zero.

future is undiscounted. Because period three deviations from zero are infinitely penalized in (8), this specification implies that the targets will be exactly reached at this date. This specification, the finite horizon equivalent to the normal requirement that the model converge to a stable steady state, is necessary if we are to make meaningful welfare comparisons across regimes, for otherwise the situation reached in period three, our equivalent of the steady state, would condition our conclusions. By imposing convergence to equilibrium in the steady state, we focus the analysis on the policy measures chosen to achieve disinflation. Consequently, in period 3 we get:

$$y_3 = z_3 = x_3 = 0 \qquad y_3^* = z_3^* = x_3^* = 0 \qquad \text{and } q_3 = 0 \tag{9}$$

This, along with (1) and (2) also implies:

$$r_3 = r_3^* = 0 \tag{10}$$

Finally, the definition of z in (7), along with (9) requires:

$$z_2 = 0 \qquad z_2^* = 0 \tag{11}$$

In words, each country must "set its house in order" before reaching the steady state: (11) states that there can be no inherited inflationary conditions at the begining of period three. Thus, each country must get rid of its initial condition ($z_o$, $z_o^*$) during periods one and two. The question we ask is which regime allows them to do that at minimal welfare cost. We will successively compare the optimal policies under freely floating exchange rates, and then within the EMS.

Our model provides each country with only one instrument, monetary policy. In the background, there is an LM curve, so that controlling money is equivalent to chosing a real interest rate. We abstract from this detail by defining monetary policy as setting the real interest rate.

There is no other instrument, namely no fiscal policy. With two policy objectives, y and x, adding fiscal policy would allow each country to achieve bliss in each period, eliminating any meaningful discussion. Indeed, regime and coordination issues only arise here because there is a scarcity of instruments. Adding fiscal policy and another policy objective would not add new insights.[10]

## 3. FREE FLOAT REGIME

The freely floating exchange rate regime is the benchmark against which the EMS must be judged, so we start with this case. We do not allow policy pre-commitments as they would not be explained by the model. Accordingly, we look for the time consistent optimal solution, working backwards from period three (equations (9) and (10) describe the behaviour in period three).

### 3.1 Period two

The overriding priority in period two is for each country to get its state variable z to zero by the end of the period. Thus, by (7):

$$y_2 = -z_1 \qquad\qquad y_2^* = -z_1^* \tag{12}$$

We now show that satisfying these binding requirements completely exhaust the degrees of freedom for policy in period two. Since $q_3 = 0$ interest parity requires $-q_2 = \bar{r}_2$ and together with equations (2) and (6′) this yields the complete solution

$$\begin{aligned} &\bar{r}_2 = k\bar{z}_1 && k=(2a+b(1-\theta))^{-1} && \\ &\overset{+}{r}_2 = (b(1+\theta))^{-1}\overset{+}{z}_1 && q_2 = -k\bar{z}_1 && \\ &x_2 = -\,gk\bar{z}_1 && x_2^* = gk\bar{z}_1 && \overset{+}{x}_2 = 0 \end{aligned} \tag{13}$$

10. Another way to introduce regime and coordination issues is to introduce uncertainty. This is the Poole approach discussed in the introduction.

Notice from equation (6′) that the sum of the core inflation rates depends on the sum of the z variables, but is independent of the exchange rate. Since both countries have driven z to zero in period two the sum of their core inflations is zero. Thus, (13) shows that they globally tighten up monetary policy by raising their average interest rate $\overset{+}{r}_2$ when they inherit global inflation $\overset{+}{x}_1 = f\overset{+}{z}_1 > 0$. If France has more inflation so that $\bar{z}_1 > 0$, it tightens up more ($\bar{r}_2 > 0$) and also appreciates its real exchange rate ($q_2 < 0$) to achieve stronger deflation ($\bar{x}_2 = -\ 2gk\bar{z}_1 < 0$).

### 3.2 Period one

Now there is a serious game to play. Each country has to plan a path for its real interest rate, knowing how it itself will act in the next period, and taking as given the interest rate path of the other country (open loop Nash). Appendix A presents the algebra when each country minimises the present value of costs subject to these constraints and to a knowledge of the structural equations. The time consistent Nash policies for interest rates imply, for France and Germany respectively,

$$Hx_1 - Jx_2 + y_1 - y_2 = 0 \quad \text{and} \quad Hx_1^* - Jx_2^* + y_1^* - y_2^* = 0 \tag{14}$$

where[11] $H = V\left(f + \dfrac{g}{a+b+\frac{b}{2ak}}\right) > 0$

$$J = V\,\frac{2akg}{a+b+\frac{b}{2ak}} > 0$$

Adding together the two parts of (14), and recalling that $\overset{+}{x}_2 = 0$ in (13) and that $\overset{+}{x}_1 = f\overset{+}{z}_1$ in (6′), we obtain:

$$\overset{+}{y}_1 = -\,\frac{1 + fH}{2 + fH}\,\overset{+}{z}_0 \qquad\qquad \overset{+}{z}_1 = \frac{\overset{+}{z}_0}{2 + fH} \tag{15}$$

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11. (14) is easy to interpret noting that H, J and 1 are, respectively and up to a multiplicative constant, the partial derivatives of $x_1$, $x_2$ and $y_1$ relatively to $r_1$ (and of $x_1^*$, $x_2^*$ and $y_1^*$ relatively to $r_1^*$).

Of course, the whole system is going to factorise into the (+) system and the (-) system since the two countries are symmetric in structure and preferences. Equation (15) together with $\overset{+}{x}_1 = f\overset{+}{z}_1$ , $\overset{+}{z}_2 = \overset{+}{x}_2 = 0$ , and $\overset{+}{y}_2 = -\overset{+}{z}_1$ completely describes the (+) system under free floating.

Equation (15) says that, in the aggregate, France and Germany have a recession in period 1 which is sufficiently large as to eliminate more than half of the initial condition $\overset{+}{z}_0$. Thus we obtain the standard result that both countries adopt overly restrictive policies to fight inflation. To see this, consider the case where a global controller minimizes $\frac{1}{2}(L + L^*)$ (or, equivalently, the world as a whole). This is the reference case as the externality is fully internalized. Then the optimal policy requires $\overset{+}{z}_1 = \overset{+}{z}_0/(2+Vf^2)$. From (14) we know that $Vf^2 < VH$ so that, indeed, $\overset{+}{z}_1$ is larger in this case (and $\overset{+}{y}_1$ less negative).

The intuition is that each country sets a high real interest rate both to get a recession to reduce z, and in the hope of an exchange rate appreciation to get inflation down. But each country neglects the fact that, in setting a high interest rate, it forces the other country to set a higher interest rate to prevent the latter country importing inflation from the former. Hence the sum of real interest rates is "too high" and the sum of outputs "too low".

The (-) system is solved by differencing the two parts of equation (14). The solution is given in Appendix A. Here we simply make two remarks for futurer reference. First, the real exchange rates $q_1$ and $q_2$ are a function of the (-) system only. Indeed, with fully symmetric countries playing Nash, the end result has to be symmetric, i.e. there can be no real exchange rate change. Changes in q can only result from asymmetries, here the difference in initial conditions.

Second, the equilibrium value $\bar{z}_1$ is:

$$\bar{z}_1 = \frac{1 + 2gkH}{2(1+2gkJ)+(f+4agk^2)H} \bar{z}_0 \tag{16}$$

Clearly, $\bar{z}_1$ is of the same sign as $\bar{z}_0$: initial conditions are not reversed during period one.

## 4. THE EMS

We define an EMS as a regime where nominal exchange rates are "usually" fixed but there are agreed rules for occasional realignments. In our three period model, we take this to mean two periods with a fixed rate and the option of one realignment. Two reasons have led us to study this particular type of exchange rate regime. First, a completely fixed nominal exchange rate seems unduly restrictive. A completely predetermined (-) system is unlikely to be a candidate for the equilibrium choice of regime (and it is shown below in footnote 12 that it is infeasible). Second, we are interested in studying at least some of the features of relevance to the European Monetary System in practice.

In our model we define $EMS_1$ as the regime which allows a realignment at the end of period one, after which nominal exchange rates are fixed for the periods two and three. $EMS_2$ is the regime in which nominal exchange rates are fixed for the periods one and two, after which there is a realignment to the steady state value of period three.

When the nominal exchange rate is fixed, the real exchange rate evolves according to the inflation differential:

$$q - q_{-1} = \pi^* - \pi \tag{17}$$

This constraint is in addition to the interest parity condition (1).

We have noted above that the evolution of q is entirely governed by the behaviour of the (-) system, which in turn is set by the difference in monetary policies, i.e. by $\bar{r}$. Imposing (17) on the flexible regime model thus amounts to absorbing the only degree of freedom available: in periods where the nominal exchange is pegged, $\bar{r}$ is set by (17), the only policy variable available being $\overset{+}{r}$.[12]

This makes it clear, then, that under $EMS_1$ all discrepancies between the two countries must be completely removed during period one so that the (-) system takes on zero values in both periods two and three. In contrast, $EMS_2$ allows convergence to be spread over the first two periods.

In what follows, we first describe the laws of motion, or structural equations, of the two economies. The key insight is that free floating, $EMS_1$ and $EMS_2$ all have the same structural equations; only the policy variables are different. This will allow us to construct an indifference map which is Lucas-invariant with respect to the choice of regime and which facilitates an analysis of the consequences of different policy choices for setting interest rates and exchange rates. We can thus give a complete analysis of the determination of the equilibrium regime.

### 4.1 $\underline{EMS_1}$

Imposing the fixed nominal exchange rate restriction (17) between periods two and three, along with the steady state conditions $q_3 = \pi_3 = \pi_3^*$, imply that $q_2 = 0$. Then (13) shows that only if all period two variables are zero in the (-) system can the (-) system converge to the required zero values in period 3. Hence under $EMS_1$, period two behaviour is trivial

$$q_2 = \bar{y}_2 = -\bar{z}_1 = x_2 = x_2^* = 0 \tag{18}$$

Core inflation rates must separately be zero since their sum is always zero in period two. The restriction $\bar{z}_1 = 0$ means that both countries must have achieved convergence by the end of period one.

12. An implication is that a monetary union is impossible unless $\bar{z}_0 = 0$. If $\bar{z}_0 \neq 0$, at some point we need $\bar{r} \neq 0$ to achieve steady state convergence.

As yet, we do not specify policy in period 1: that is what the game to establish the EMS will determine. Rather, we note the effect the restrictions of equation (18) place on the structural equations in period one. To satisfy the equations of the (-) system we require (see Appendix A):

$$\bar{y}_1 = -\bar{z}_0 \qquad q_1 = -k\bar{z}_0 \qquad \bar{x}_1 = -2gk\bar{z}_0 \qquad \bar{r}_1 = k\bar{z}_0 \tag{19}$$

This is the sense in which the EMS forces cooperation and convergence. If $\bar{z}_0 > 0$, we have $q_1 < 0$: France must raise its interest rate more than Germany and appreciates its currency as it must deflate faster (the cost is $\bar{y}_1=-\bar{z}_0<0$).

Yet, there remains one degree of freedom: now the only role left for policy is to choose $\overset{+}{r}_1$, which will determine the entire path of the (+) system. It is easier simply to think of policy as choosing $\overset{+}{z}_1$ directly and note that

$$\overset{+}{x}_1 = f\overset{+}{z}_1 \qquad \overset{+}{x}_2 = 0 \qquad \overset{+}{y}_2 = -\overset{+}{z}_1 \qquad \overset{+}{y}_1 = \overset{+}{z}_1 - \overset{+}{z}_0 \tag{20}$$

and each country's variables may then be recovered using $x = ½(\overset{+}{x}+\bar{x})$, $x^* = ½(\overset{+}{x}-\bar{x})$, etc.

One final point should be noted. Although it is true that in period one both countries must reach agreement to ensure $\bar{z}_1 = 0$, when period two comes along, equation (19) satisfies the usual equations for free floating; it just happens to have a particular initial condition for period two. In this sense, the $EMS_1$ regime is time consistent and, when established in period one, does not incorporate incredible commitments for period two.

### 4.2. $EMS_2$

Since $EMS_2$ allows a realignment at the end of period two, behaviour in period two is identical to that under free floating and imposes no special requirements for initial conditions to be inherited from period one.

To the equations describing free floating behaviour in period one we must now add the additional restriction that real exchange rate changes between periods one and two reflect differential inflation rates. Using equations (3)-(5) and the interest parity condition (1) we can express this additional restriction as (see Appendix A):

$$(1+2\theta)\bar{r}_1 = c\bar{z}_1 - \bar{x}_1 \tag{21}$$

Substitution of this condition into the structural equations for free floating, but disregarding the previous equations for Nash interest rate setting, yields the complete solution for the (-) system. Specifically.

$$\bar{z}_1 = E\bar{z}_0 \quad \text{with} \quad 0 < E = \frac{k(1+2\theta(1-d))}{c(1-d)+4a\theta(1-d)k^2+k(1+2\theta+2ak)} < 1 \tag{22}$$

where it will be recalled that f=dc, g=d$\theta$, and d is the positive fraction governing the partial adjustment of core inflation to actual inflation. Thus $EMS_2$ eliminates some fraction E of the initial disparity $\bar{z}_0$ by the end of period one, the remaining disparity being eliminated in period two.

Other values of the (-) system in $EMS_2$ are easily recovered from the structural equations in Appendix A. The role of policy and the subject of the game to establish rules for $EMS_2$ is to select the value of $\overset{+}{r}_1$ (or equivalently $\overset{+}{z}_1$, see (A.4)) which will determine the (+) system.

### 4.3. The Choice of Regime

Choosing either $EMS_1$ or $EMS_2$ commits both countries to a particular path for the (-) system, and the remaining game within either regime determines the evolution of the (+) system. The third possible regime is free floating with Nash interest rate rules. We now wish to discuss which regime will be chosen. If either EMS regime is to be chosen it must offer both countries at least as much utility as they enjoy under free floating.

Since all three regimes merely choose different values of the policy variables within the same structural equations we can draw indifference maps which apply to all three regimes. It is most convenient to depict utility as a function of $\overset{+}{z}_1$ and $\bar{z}_1$.

The details are presented in Appendix B. The quadratic form of the loss functions (8) means that the indifference curves are ellipses. They are shown in Figure 1. It will be useful for the following discussion to make explicit the coordinates of each country's indifference curves center, shown as C and $C^*$, respectively, in Figure 1:

$$
\begin{aligned}
&\text{France} : && \bar{z}_1(C) = 2a(2gk\bar{z}_0 - fz_0)/D \\
& && \overset{+}{z}_1(C) = [2a(fz_0 - 2gk\bar{z}_0) + 2g((1+4a^2k^2)z_0 + gVfk\bar{z}_0)]/D \\
&\text{Germany} : && \bar{z}_1(C^*) = 2a(2gk\bar{z}_0 + fz_0^*)/D \\
& && \overset{+}{z}_1(C^*) = [2a(fz_0^* + 2gk\bar{z}_0) + 2g((1+4a^2k^2)z_0 - gVfk\bar{z}_0)]/D
\end{aligned}
\tag{23}
$$

where $D = g\,[2(1+4a^2k^2) + Vf^2] > 0$.

These points represent the best that each country can achieve given the initial conditions $\overset{+}{z}_0$ and $\bar{z}_0$ (or, equivalently, $z_0$ and $z_0^*$ ). In general, this will not represent complete bliss ($L = 0$, $L^* = 0$).

Although (23) looks pretty bad, it yields a certain number of useful restrictions. First, it can be shown[13] that $\overset{+}{z}_1(C) > 0$.

Second, clearly $\bar{z}_1(C^*) > 0$. Third, it is shown in Appendix B that $\overset{+}{z}_1(C) > \overset{+}{z}_1(C^*)$ and that $\bar{z}_1(C) < \bar{z}_1(C^*)$. Hence, France's most desired position C lies northwest of Germany's most desired position $C^*$, C is always above the horizontal axis, and $C^*$ always to the right of the vertical axis. Typically, in period one, France would like Germany to expand, and Germany would like France to contract. In fact, each wants the other to bear the maximum possible share of the joint adjustment burden, and France wishes more moderate contraction for the EMS as a whole.

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13. Note that $\bar{z}_0 < z_0$ when $z_0^* > 0$, so that:
$2a(fz_0 - 2gk\bar{z}_0) + 2g(1+4a^2k^2)z_0 > [(f-2gk) + 2g(1+4a^2k^2)]z_0$ and the bracketed expression is equal to: $2a(f+2gk) + 2g(1-2ak)^2 > 0$.

We also note that a sufficient, but not necessary, condition for $\bar{z}_1(C)$ to be negative, is that (f-2gk) is positive. It turns that this condition is necessary, but not sufficient, for France to have higher core inflation than Germany in period one under a free float. Because this situation is appealing, we draw Figure 1 assuming that this condition holds. The analysis can be easily extended to the opposite case. Finally, the sign of $\overset{+}{z}_1(C^*)$ is also ambiguous. Accordingly we distinguish two cases: in Figure 1(a) $\overset{+}{z}_1(C^*)$ is positive, and it is negative in Figure 1(b).

To these indifference curves correspond the Nash reaction functions implied by the interest rate rules. They are shown in Figure 1 as FF for France, and GG for Germany[14]. Their intersection determines the Nash equilibrium under a free float at point N whose coordinates are:

$$\begin{aligned} \bar{z}_1(N) &= (1+2gkH)\bar{z}_0/S \\ \overset{+}{z}_1(N) &= \overset{+}{z}_0/(2+Hf) \end{aligned} \tag{24}$$

where $S = 2 + Hf + 2gk(J+2akH)$. Both coordinates are positive. Note that as long as $\bar{z}_1(C) < 0$, because C and N both lie on the downward sloping line FF, C must be northwest of N. As $\overset{+}{z}_1(C^*)$ is ambiguous, $C^*$ may move along GG on both sides of N, as shown on Figures 1(a) and 1(b). A special case is when $C^*$ and N coincide, so that Germany is happiest under a free float, which is then the equilibrium regime. Unfortunately, there is no easy interpretation of this case.

In Figure 1, the $EMS_1$ regime is represented by the vertical axis, since we then have the restriction $\bar{z}_1 = 0$. Similarly, equation (22) shows the value of $\bar{z}_1$ under $EMS_2$ and we draw a vertical line at this value.

Clearly the Nash equilibrium under free floating is inefficient, and the shaded areas in Figure 1 illustrate the regions in which Pareto gains can be

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14. Where the FF line intersects a French indifference curve, the slope of the curve is $kb(1+\theta)(1+2ak)>0$ (since it corresponds to $r^*_1 = ct$, see (A4) and (A5)). Similarly, where GG intersects a German indifference curve, the slope of the curve is the opposite and therefore negative.

achieved. In Figure 1(a) the gain comes chiefly from the possibility of expanding aggregate output. In Figure 1(b) it comes essentially from reducing disparities between the two countries.

In the rest of this section we investigate under which conditions an EMS will emerge as the equilibrium regime. This will be the case if one of the EMS lines goes through the shaded area, so that both countries may achieve welfare gains by adopting the corresponding regime. As is clear from the outset, while an EMS may offer welfare gains, there remains a secondary game: agreeing upon a specific point on the portion of the vertical EMS line which goes ghrough the shaded area. This shows that adopting the EMS still leaves one degree of freedom, and therefore a source of conflict. The EMS does not promote full coordination, yet requires it.

In Figure 1(a) Germany will decline $EMS_1$ whatever the details of its monetary policy: Germany is better off under free floating. Only in Figure 1(b) does there exist a version of $EMS_1$ which is superior to a free float. In Figure 1(a) $EMS_2$ is unambiguously the equilibrium regime. In Figure 1(b) $EMS_1$ is unambiguously the equilibrium regime: although a small portion of the $EMS_2$ line may beat free floating, a Pareto gain will still be achieved by moving from $EMS_2$ to the relevant portion of the vertical axis.[15] Whether the world looks like Figure 1(a) or 1(b) is therefore a matter of some importance.

The diagram is influenced both by the model parameters and by the initial conditions. In the next section we discuss the role of policy preferences. The following section analyses the role of initial conditions.

[Figure 1 about here]

### 4.4 The role of policy preferences

15.There is no restriction on whether the free float point N lies right or left of the $EMS_2$ line. It is possible therefore to have the $EMS_2$ line going through the shaded area left of N on Figure 1(b).

First, we consider the role of the (common) aversion to inflation V. The limit case of V infinite is one where the Nash solution lies on the horizontal axis while the French and German bliss points are along the vertical axis, symmetric relatively to the origin (see Appendix B). As V decreases from infinity, the movement of points C, $C^*$, and N is shown in Figure 2(a). The case of V infinite is the limit case of figure 1(b), and as V decreases we move from Figure 1(b) to Figure 1(a). A high aversion to inflation increases the desire to converge fast to the zero-inflation steady state, hence to reduce disparities. This rules out $EMS_2$ which allows for a late realignment. The floating regime solution (with $\bar{z}_1 > 0$) is therefore highly inefficient, which makes $EMS_1$ (with $\bar{z}_1 = 0$) very attractive. Yet, $EMS_1$ may not emerge as the solution as the absolute preferences of France (which wants $\overset{+}{z}_1 > 0$) and Germany (which wants $\overset{+}{z}_1 < 0$) are opposite.[16] If $EMS_1$ is the equilibrium, Figure 1(b) shows that it will be globally more contractionary than the Nash float regime, more than France wishes, but less than Germany's preferred solution.

### 4.5 The role of initial conditions

We consider next the role of $\overset{+}{z}_0$, the measure of global inflation inherited from the past. The limit case of $\overset{+}{z}_0 = 0$ is shown on Figure 2(b): it resembles the case of V infinite, except that C and $C^*$ lie along a vertical line with a

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16. With V infinite, France achieves bliss when $x_1=x_2=0$. Given that in any case $z_2=0$, $x_2=0$ requires $q_2=0$, this will only be possible if in period two there is no need to use the real exchange rate, i.e. if $\bar{z}_1=0$. In turn, $\bar{z}_1=0$ requires France to strongly deflate, hence $\bar{r}_1>0$ and $q_1<0$. Thus $x_1=fz_1+gq_1=0$ for $z_1>0$. Germany equally wants $\bar{z}_1=0$ to achieve $q_2=0$ and $x_2^*=0$. But with $x_1^*=fz_1^*-gq_1$, accepting $q_1<0$ to achieve $\bar{z}_1=0$, means that Germany will want $z_1^*<0$ to reach $x_1^*=0$. Since $\bar{z}_1=0$ is desired by both countries, both want $z_1=z_1^*$, but France wants $z_1>0$ and Germany $z_1^*<0$, hence a conflict.

positive abscissa when $4gk-f > 0$ (see (23)). Holding $\bar{z}_0$ constant, when $\overset{+}{z}_0$ increases the vertical $EMS_1$ and $EMS_2$ lines are unaffected. Both Nash reaction functions shift up parallel by the same amount and the free float equilibrium point N rises vertically above the original point (see Figure 2(b)). Appendix B establishes that, with higher $\overset{+}{z}_0$, the centres C and $C^*$ move up by the same amount but move apart. This proves that $C^*$ must rise relative to N. In other words it makes Figure 1(a) more likely. There are thus three relevant ranges of $\overset{+}{z}_0$. If $C^*$ is sufficiently close to N, Germany will be almost at its best possible situation under a free float and will not join any EMS. If $\overset{+}{z}_0$ is higher than some critical value, $EMS_2$ is the equilibrium regime and we are in Figure 1(a). If $\overset{+}{z}_0$ is below some critical value we are in Figure 1(b) and $EMS_1$ is the equilibrium regime. The critical values of $\overset{+}{z}_0$ are not independent of $\bar{z}_0$ but the preceding statements hold for any given $\bar{z}_0$.

Now consider changes in $\bar{z}_0$ holding $z^+{}_0$ constant. The limit case of $\bar{z}_0 = 0$ is shown in Figure 2(c). Of course, when $\bar{z}_0 = 0$, we have complete symmetry. As $\bar{z}_0$ increases, the vertical distance between C and $C^*$ becomes larger, their horizontal difference being unaffected. Moreover a larger $\bar{z}_0$ implies that the two reaction functions under free floating have intercepts further from the origin, intersecting at a new point N which lies horizontally to the right of the original point N (see Appendix B). This means that $C^*$ must occur at a lower $\overset{+}{z}_1$ the larger is $\bar{z}_0$. Moreover, the vertical $EMS_2$ line shifts to the right in proportion to N. Hence larger $\bar{z}_0$ unambiguously increases the likelyhood of Figure 1(b) and of $EMS_1$. Again, there is a critical neighbourhood which places $C^*$ sufficiently close to N that Germany will wish to float, but as $\bar{z}_0$ exceeds the critical value $EMS_1$ is the equilibrium regime, whilst below some critical value of $\bar{z}_0$ $EMS_2$ is the equilibrium regime.

[Figure 2 about here]

### 4.6 Assessment: the Optimal Timing of Realignment

Because we describe the free float regime as a Nash solution, it is Pareto inefficient and an EMS, a form of cooperation to internalize the externalities, is likely to be a superior solution. However, the EMS is not a well defined solution: we need to specify the rules of the game for such crucial parameters as the timing of allowed realignments (i.e. $EMS_1$ versus $EMS_2$) and the distribution of gains (i.e. the chosen position along the EMS line). The next section deals with this last issue, here we concentrate on the choice between $EMS_1$ and $EMS_2$.

$EMS_1$ is a version which forces early convergence by permitting only an early realignment, and effectively imposing a monetary union thereafter. It certainly occurs when $\bar{z}_0=0$, and possibly when the aversion to inflation is high. Its occurence is also enhanced by a large $\bar{z}_0$ if $f>4gk$, i.e. when France and Germany start from very different initial conditions and when the Phillips curve is a powerful channel for deflation. Under these conditions, real exchange rate changes are not worth exploiting to correct for the initial divergence, either because they are ineffective, or because the initial conditions are too different.

Although $EMS_2$ bans an early realignment, it offers more freedom as monetary authorities can use real exchange rate changes to reduce their differences in initial conditions. Accordingly it is likely to emerge with a large value of $\bar{z}_0$ if $f < 4gk$, i.e. when inflation is relatively more sensitive to the exchange rate than to the level of activity. $EMS_2$ is also more likely to be the equilibrium regime when aversion to inflation is low, so that the authorities are willing to adopt progressive policies rather than a "cold turkey" approach, and when average inherited inflation $\overset{+}{z}_0$ is large, so that reducing it must be spread over time.

The free float rate regime is more likely to emerge for intermediate values of V and $\overset{+}{z}_0$ when Germany sees little benefits in adopting the EMS. The same occurs for intermediate values of $\bar{z}_0$ if the Phillips curve effect is strong enough.

### 4.7 Division of gains and the scope for leadership

Even when an EMS emerges as the equilibrium, the solution generally remains undetermined. Both countries still have to agree on a specific point along the portion of the EMS line which goes through the Pareto improving region. Thus there exists several divisions of gain compatible with the EMS.

Analytically, this problem can be tackled by modelling an explicit bargaining game. Our purpose in this section is more limited. We wish to explore whether the postulated initial conditions create some scope for one country acting as a Stackelberg leader. This question is related to the on-going suspicion that Germany has so far exerted leadership within the EMS. The reasoning is usually cast in terms of policy credibility. We investigate here whether other features may also help explain such an outcome.

Consider Figure 1(a). Suppose Germany is allowed unilaterally to determine the monetary policy in $EMS_2$ the equilibrium regime. It will choose the point of tangency of its ellipse to the vertical $EMS_2$ line (point G). This point happens to be quite close to the contract curve connecting C and $C^*$. As drawn, it also gives France a larger benefit from $EMS_2$ than it gives Germany. In short, it is not clear that France would object to "German leadership". Of course, France is not at its most desired position. If for given French output and $z_1$, it could persuade Germany to increase German output yet further, this would raise $\overset{+}{z}_1$ and reduce $\bar{z}_1$, moving France to an even better position. Thus Figure 1(a) is compatible with a world in which France accepts German leadership in $EMS_2$ but is always complaining that German output is too low in period one.

Staying with Figure 1(a), we can see that French leadership is not a viable proposition. If France chooses the tangency of its ellipse to the $EMS_2$ line (point F), Germany would rather have free floating. Hence we can derive behaviour not unlike that which casual observation suggests characterises the world in the 1980s, even though our model has symmetric preferences and symmetric structures. A difference in initial conditions is sufficient.

Now suppose it is Figure 1(b) that is relevant. $EMS_1$ is the equilibrium regime, and again Germany will revert to floating before accepting French leadership. Now, however it is conceivable that $C^*$ lies sufficiently below N that the tangency chosen by Germany lies beneath the French indifference curve which goes through N. If so, Germany will not be able unilateraly to determine policy within $EMS_1$.

## 5. CAPITAL CONTROLS UNDER A FREE FLOAT

The experience so far with the EMS has been characterized by the existence of capital controls in several member countries. This fact raises two largely unrelated questions The first one is whether capital controls are required to make the EMS viable. Work based on the literature on balance of payment crises suggests that capital controls indeed may be a useful device to make realignments relative easy to manage.[17]

A different question is whether capital controls alter the characterestics of the game in a way that makes the EMS more likely to Pareto dominate a free float. We will see that this is the case, yet in a limited sense. In this section, we show the working of capital controls in our model, first by considering the free float regime. To make full use of the preceding model in which perfect capital mobility was assumed, we adopt the simple expedient of viewing capital controls as the choice of a tax rate on interest from international assets, with perfect capital mobility continuing to hold with respect to post-tax interest rates. We readily recognize that regulations on the capital account may affect the degree of asset substitutability, especially when perfect certainty is removed. However, we are keen to maintain a model in which the policy game can be shown to have a tractable analytical solution. Unquestionably, the assumptions we have made are most conducive to that end.

Even then, there remains a difficulty which we need to avoid. Suppose France levies a tax t on interest earnings from abroad by French residents, and a tax or subsidy T on French interest payments to overseas residents. Consider a French lender making a round trip to Germany during the period. The post-tax parity condition is

$$q_{+1}-q = r-(r^{*}-t)$$

whilst for a German lender making a round trip to France it is

$$q_{+1}-q = r-T-r^{*}$$

If these two conditions are not equivalent, there is a risk of flipping backwards and forwards between the two countries at the relevant marginal

17. See Wyplosz (1986), Giavazzi and Pagano (1985).

condition. To avoid this possibility, we assume that if France imposes controls, it sets $t+T=0$, thus subsidising foreign lenders if it taxes residents lending abroad. From a balance of payments viewpoint this makes perfectly good sense. Similarly, we assume that Germany sets $t^*+T^*=0$ if it adopts controls.

Controls represent an additional policy instrument, and if they come free they are likely to be used. Since we have not included any cost of using monetary policy in our loss function, should we view the costs of operating capital controls as being qualitatively different? One could argue that they are not, and sometimes, to obtain particularly clean expressions facilitating simple comparisons, we shall investigate this case. Alternatively, one might argue that an exchange control system imposes a fixed cost to set it up and operate it. We shall assume that a country operating capital controls must pay a fixed welfare cost of M per period. The cost of controls in period two is independent of whether controls were used in period one - otherwise the game is considerably more complicated - so this formulation neglects the interesting possibility that some set up costs are incurred only once.

We now characterise equilibrium with floating exchange rates and the possibility of capital controls. In period three both countries are in steady state and controls are unnecessary. We begin the analysis in period two.

### 5.1 Period two

Recall that in the absence of controls,

$$y_2 = -z_1 \qquad y_2^* = -z_1^* \qquad q_2 = -k\bar{z}_1$$

$$x_2 = -gk\bar{z}_1 \qquad x_2^* = gk\bar{z}_1$$

whence, as viewed from period two, costs under free floating are

$$L_2 = z_1^2 + vg^2k^2\bar{z}_1^2 \qquad L_2^* = z_1^{*2} + vg^2k^2\bar{z}_1^2 \tag{25}$$

Each country bears whatever output costs is necessary to drive z to zero. Countries have core inflation with equal magnitude but opposite sign. Since they equally dislike positive and negative core inflation, they have the same inflation cost and would both like to see it driven to zero; with $z_2 = z_2^* = 0$, a real exchange rate $q = 0$ would give them both zero core inflation in period two (see equation (6′). Unfortunately, with just one interest rate instrument each in period two, they are too preoccupied with driving z to zero in each country to be able to drive q to zero as well.

Now admit the possibility of capital controls. Suppose France installs capital controls and acts on the assumption of no German retaliation. France will use the interest rate tax to ensure $q_2 = 0$, for then France will have no core inflation. In pursuing its selfish interest, France creates exactly the same benefit for Germany, which also has $x_2^* = 0$ when $q_2 = 0$. This proves that Germany will not retaliate with controls of its own. France has incurred the fixed cost M of controls, and costs are now given by

$$L_2 = z_1^2 + M \qquad\qquad L_2^* = z_1^{*2} \tag{26}$$

A necessary condition for France to impose controls in period two is that the cost M is less than the benefit, namely avoiding the inflation cost $Vg^2k^2\bar{z}_1^2$ under a free float. Unfortunately, identical reasoning applies to Germany. The model cannot determine which country will impose controls (unless we postulate different fixed costs), but it does give the condition under which one of the two countries will adopt controls. And as M tends to zero, the probability that controls will be used tends to unity.

### 5.2 Period one, conditional on controls being used in period two

Behaviour in period one is contingent on whether or not there will be controls in period two. We begin with the simpler case in which players in period one anticipate that controls will be used in period two. When controls come free, we have seen that they will indeed be used in period two. However, when controls incur a fixed cost M, we saw that they would be used only if $\bar{z}_1$ was sufficiently large. Hence we shall have to verify whether this condition is satisfied; if not, the relevant equilibrium, if it exists, will be one in which players in period one anticipate no controls in period two.

When period two controls are anticipated, we show in Appendix C that the Nash interest rate rules in period one are given by

$$Nx_1 + y_1 - y_2 = 0 \qquad Nx_1^* + y_1^* - y_2^* = 0 \tag{27}$$

with $N = V(f+\frac{g}{a+b})$.

Since it is foreseen that $x_2 = x_2^* = 0$, core inflation in period two no longer enters the decision problem or the optimal rule for either country.

Proceeding as in the freely floating case of the previous section, we obtain separate solutions for the (+) system and the (-) system. The (+) system is given by

$$\overset{+}{y}_1 = -\frac{1 + fN}{2 + fN}\overset{+}{z}_1 \qquad \overset{+}{z}_1 = \frac{\overset{+}{z}_0}{2 + fN} \qquad \overset{+}{x}_1 = f\overset{+}{z}_1 \tag{28}$$

Comparing this with equation (15), the solution of the (+) system when capital controls are not employed in period two, and noting that N exceeds H (compare (14) and (27)), we conclude that the use of capital controls in period two leads to a larger recession in period one. Since we argued earlier that free floating already undertook too much of the two-period recession in period one, the addition of second period capital controls exacerbate this distortion.

This result is simply explained when it is recalled that H and N reflect the magnitude of the effect of each country's period one monetary policy on period one core inflation. Suppose, in period one, France contemplates a higher interest rate $r_1$. This will reduce core inflation by lowering demand directly, and also because of a period one real appreciation. The real appreciation, in turn, results from interest arbitrage given $q_2$. Under free floating $q_2 = -k\bar{z}_1$, as France must appreciate in period two to reduce its larger inherited inflationary condition. So a higher interest rate $r_1$, which reduces $\bar{z}_1$, implies less of a depreciation in period two, this last effect working towards less of an appreciation in period one, hence less of a contraction. With capital controls in period two, $q_2 = 0$ and therefore there is no offsetting effect on $q_1$. Hence a monetary contraction in period one exercises a more powerful effect in period one when capital controls are expected for period two. More effectiveness means more temptation to use monetary policy. As the same applies for Germany, with controls in period two both countries choose higher first period interest rates than under free floating.

The solution for the (-) system is given in Appendix C. We reach two conclusions at this stage. First, the behaviour of the (+) system in period one depends upon the controls being used in period two, but not upon period one controls, as shown by (28). Second, the (-) system in period one does depend on period one controls. The reason is that the (+) system must go from $\overset{+}{z}_0$ to the value of $\overset{+}{z}_1$ given by (28), hence leaving no degree of freedom.

Suppose first that controls are not used in period one. The solution is then (see again Appendix C):

$$\bar{x}_1 = \frac{f - 2gk}{2 + N(f+2gk)} \bar{z}_0 \tag{29}$$

Hence, taking $z_0$, $z_0^*$, and $\bar{z}_0$ as positive,

$$\bar{x}_1 \gtrless 0 \qquad \text{as} \qquad f - 2\,gk \gtrless 0 \tag{30}$$

f is the responsiveness of core inflation to output in the domestic Phillips curve and g is the responsiveness of core inflation to a real depreciation of the exchange rate, through its induced effect on import prices. When the domestic Phillips curve effect dominates, the outcome is qualitatively the same as if there were two unlinked economies. Each wants to spread the burden of disinflation over the two periods, and the country starting with the higher core inflation or more adverse initial conditions still has larger core inflation by the end of period one. In contrast, when the exchange rate is the more powerful channel of disinflation, France, with more of a problem to handle, needs a big real appreciation and ends up exporting sufficient of its inflation to Germany in period one that Germany then has higher core inflation than France.

Now admit the possibility of controls in period one. Each country can choose an interest tax rate and manipulate the exchange rate independently of interest rates. Changing the exchange rate affects y, z, and x in each country in period one, but subject to the restriction that the (+) values of these variables are unaffected by controls.

Since $y_1 = z_1 - z_0$ and since equation (27) the optimal interest rate rule is Lucas-invariant with respect to interest taxes, it is convenient to express $y_1$ and $z_1$ as functions of $x_1$ for France, and $y_1^*$ and $z_1^*$ as functions of $x_1^*$ for Germany. Hence, given the optimal interest rate rules but prior to optimising on capital controls, welfare costs may be written as

$$L_1 = (V+N^2/2)x_1^2 + z_0^2/2 \qquad\qquad L_1^* = (V+N^2/2)x_1^{*2} + z_0^{*2}/2 \qquad (31)$$

where, from equation (28), the sum of $x_1$ and $x_1^*$ is predetermined with respect to the game to set tax rates in period one. Let X denote this level of $\overset{+}{x}_1$. Hence German welfare costs may be written in terms of French core inflation $x_1$.

$$L_1^* = (V+N^2/2)\ (X-x_1)^2 + z_0^{*2}/2 \qquad (32)$$

Now we make use of condition (30). Suppose first that (f-2gk) is positive. In the absence of period one controls, France would have larger core inflation in period one than Germany, so $x_1$ exceeds X/2. In Figure 3 we show $x_F$ at such a level. We also plot as solid curves the level of French and German costs as functions of $x_1$. When $x_1 = 0$ France has no core inflation in either period, and minimises the output cost of eliminating $z_0$ within two periods by doing half the adjustment in each period. Hence the minimum value of $L_1$ occurs when $z_1 = ½z_0$, where $L_1 = ½\ z_0^2$. Similarly, German costs are minimised when $x_1^* = 0$ and $x_1 = X$ in which case German costs are $L_1^* = ½z_0^{*2}$. (Actually, since this analysis is conditional on controls in period two, one country also has the fixed cost M for period two, but this is irrelevant in the ensuing analysis.)

[Figure 3 about here]

If controls are not used in period one, France is at point A and Germany at point B. Each country can set a tax rate and hence affect the exchange rate and thus $x_1$. How does the game go ?

Suppose each plays Nash, treating the other country's tax rate as given. Whatever particular rate France assumes that Germany sets, France will then choose the tax rate that makes $x_1 = 0$. Since France also has to incur the fixed cost of controls, it thus moves from A to E in the diagram. Provided the fixed cost of controls is sufficiently small, A lies above E so France wants controls. But with $x_1 = 0$, Germany is extremely miserable. It would certainly pay the fixed cost M to set a tax rate to make $x_1 = X$ taking Germany to point F, at which point France is extremely miserable and must retaliate again. This is a zero-sum game, and the Nash reaction functions are parallel. In short, we cannot appeal to static Nash equilibrium as a solution concept.

However, a slight reformulation will provide a unique equilibrium to this potential retaliation war. Suppose in addition to the fixed cost M of having controls, there is an additional cost m every time a country changes its tax rate during a retaliation war. We replace static equilibrium by perfect equilibrium in a dynamic game to set tax rates, it being understood that this retaliation game is of infinitely short duration since intelligent participants will in fact locate the perfect equilibrium with constant tax rates immediately.

To spell out how this works, consider Figure 4. Interpret the solid curves as $L + M$ and $L^* + M$ inclusive of the costs of having controls, and the dotted curves as showing the cost $L + M + m$ and $L^* + M + m$ inclusive of one more round of retaliation.

[Figure 4 about here]

Conjecture the retaliation has a unique steady state $x'$. France is at W and Germany at V. Suppose France contemplates one more round of retaliation, reducing $x_1$ from $x'$ to $x'-h$. The most France can cut $x_1$ without German retaliation is an amount h such that

$$L^*(x'-h) = L^*(x') + m$$

whilst France will be prepared to incur the marginal cost of retaliation only if

$$L(x'-h) + m = L(x')$$

We consider a retaliation game in which the cost m tends to zero. Thus the unique equilibrium of the game is the value of $x_1$ satisfying

$$\frac{dL}{dx_1} + \frac{dL^*}{dx_1} = 0 \tag{33}$$

Given the symmetry of L(.) and $L^*(.)$ this occurs when

$$x_1 = x_1^* = X/2 \tag{34}$$

Together with the equations derived in Appendix C we can give the full solution when M = 0. Letting $Z = \pm\bar{z}_0/(2+fN)$, whence $X = fZ$, we get:

$$\begin{aligned} x_1 &= \tfrac{1}{2}fZ \qquad x_2 = 0 & x_1^* &= \tfrac{1}{2}fZ \qquad x_2^* = 0 \\ z_1 &= \tfrac{1}{2}(Z+\tfrac{1}{2}\bar{z}_0) & z_1^* &= \tfrac{1}{2}(Z-\tfrac{1}{2}\bar{z}_0) \\ y_1 &= \tfrac{1}{2}(Z+\tfrac{1}{2}\bar{z}_0-2z_0) & y_1^* &= \tfrac{1}{2}(Z-\tfrac{1}{2}\bar{z}_0-2z_0^*) \end{aligned} \tag{35}$$

Note that these equations imply $\bar{z}_1 = \tfrac{1}{2}\bar{z}_0$. Half the initial disparity is removed in the first period. Earlier, from equation (25) we argued that controls would be used in period two if $g^2k^2\bar{z}_1^2$ exceeded M. When M = 0 this condition holds and (35) is unambiguously the solution.

Notice what is implied from Figure 3. If (f-2gk) is positive - the Phillips curve being more powerful than exchange rate appreciation as the channel of disinflation - the free float value $x_F$ exceeds ½X. When capital controls come free, both countries use controls in both periods, and with $x_1$ = ½X, France gains from the use of controls and Germany's best response, the use of controls, leaves it worse off than under a free float. Germany would dearly love an international precommitment not to use capital controls. Conversely, if $(f-2gk)$ is negative, the free float equilibrium has $x_1$ less than ½X. Again both countries use controls, but now Germany benefits at the expense of France.

Next suppose that the cost of controls M is strictly positive. Initially, we assume that the free floating value $x_F$ exceeds ½X as in Figure 3. If there is a retaliation war the outcome is again $x_1 = ½X$, but France can actually do better than this: it can exploit Germany's fixed cost M. Starting from the free float equilibrium, it is France that wants controls. If France sets the tax rate and the level of $x_1$ such that German costs satisfy

$$L^*(x_1) = L^*(½X) + M \tag{36}$$

it is just not worth Germany setting up controls in order to retaliate. Hence France can drive $x_1$ to the left of ½X, and more so the larger is M. However, if M is sufficiently large the gain France obtains does not pay for the fixed cost incurred by France. In the former case, equation (36) determines the equilibrium value of the (-) system, in the latter case controls are not used at all in period one. In either case, we have found the full equilibrium of the policy game provided $g^2k^2\bar{z}_1$ exceeds M, thereby validating the conjecture that it will indeed be optimal to use controls in period two (see equation (25)).

To sum up, provided it is optimal to use controls in period two, the (+) system is independent of whether or not controls are used in period one. Period one controls cannot secure Pareto improvements but redistribute welfare between the two participants. It is the country which would have high period one core inflation under a free float which stands to gain from period one controls, and it will enjoy this gain unless the fixed cost of controls is so large that it dominates this potential gain.

### 5.3 Period one, conditional on the absence of controls in period two

With controls in period two, both countries had zero core inflation in period two. Basically, each country wanted to use period one controls simply to reduce $x_1$ or $x_1^*$. Since the (+) system was independently determined, the control game was a game about distributing period one differences. In the absence of controls in period two, this is no longer the case. The (+) system is still predetermined with respect to the game over the (-) system, but now decisions about (-) variables in period one also affect $x_2$ and $x_2^*$: since $\overset{+}{x}_2$ = 0 core inflation in period two belongs exclusively to the (-) system.

For this reason, it is no longer true that $L_1$ and $L_1^*$ are minimised at $x_1 = 0$ and $x_1 = \overset{+}{x}_1$ respectively. Nor is it true that with $M = 0$ the retaliation game would lead to $x_1 = \frac{1}{2}\overset{+}{x}_1$. However, the qualitative results remain the same. Of course this is only a reference case: with $M = 0$ controls will definitely be used in period two and the analysis of the previous section will apply. With M greater than zero, the analysis of the previous section carries over: the country desiring the controls will be able to exploit the other country's fixed cost, and will nevertheless have to check that it can still get sufficient welfare gain to cover its own fixed cost of controls.

## 6. THE EQUILIBRIUM REGIME WITH CAPITAL CONTROLS

In this final section, we examine how the possibility of capital controls affects the choice of exchange rate regime. To place an upper bound on this effect, we assume that capital controls are costless to employ, in which case they will generally be used.

As we have already explained, exchange rate rules impose additional restrictions on the (-) system whereas capital controls remove restrictions on the (-) system. Thus an EMS with cooperative decision making both about exchange rate rules and about capital controls is essentially a recipe for rediscovering the contract curve. Cooperation ensures that externalities are internalised, and capital controls remove the restriction or penalty on this form of cooperation. In one sense this insight is important, but in another sense it is not: we suspect the EMS is not merely a vehicle to reintroduce a mythical global controller who seeks and locates the Pareto-efficient outcome.

Rather, in this paper, we have sought to place greater structure on the sequence of bargaining that actually takes place. Thus, while blind mathematics establishes that an EMS with capital controls <u>can</u> dominate any of the regimes we have previously discussed - the proof being so trivial that we omit it entirely - our purpose instead is to investigate whether there exists simple regime which both countries would wish to join and, having joined, would remain within.

This is already a long paper, and a complete analysis of this issue would make it considerably longer. So we simply indicate how the analysis of the previous two sections may be extended. To this end, we focus our attention on a narrower question: under what circumstances would both countries prefer one particular regime to the alternative of floating exchange rates with costless capital controls? The latter is the equilibrium described in equations (28) and (35).

The regime we shall investigate is $EMS_1$ with an agreement to adopt capital controls only during period one. Why not allow capital controls in both period one and period two? This would essentially unscramble the EMS restrictions and restore the free floating with capital controls equilibrium with which we wish to compare the EMS regime. Hence the interesting case to study is one in which capital controls are employed in period one but there is a credible commitment to remove them in period two. It will be credible for countries in period one to promise to give up controls in period two when they plan to leave initial conditions for period two which would then make it unnecessary to use controls in period two. In the absence of controls in period two, equation (18) implies that convergence must have been fully accomplished before period two under $EMS_1$

$$q = \bar{y}_2 = -\bar{z}_1 = x_2 = x_2^* = 0 \tag{18}$$

If at period two each country inherits the same z, the exchange rate $q_2$ will in any case be zero, the only objective of policy will be to set $y_2 = -z_1$ in each country, which can be accomplished without capital controls. Hence a credible promise to give up period two controls is simply an undertaking to achieve $z_1 = z_1^*$.

In period one, controls can be used and will be used if their cost is nil. What concerns us here is whether the choice between free floating and $EMS_1$ is altered by the presence of controls. This question is very hard to answer in general, so we focus here on a particular version of the game: France unilaterally chooses the level of capital controls in period one and Germany unilaterally chooses the common value of $z_1$, both countries being pledged to abandon controls in period two.[18]

France chooses capital controls, and therefore the exchange rate, to drive its core inflation to zero in period one. Thus:

$$x_1 = 0 \qquad\qquad x_1^* = 2fz_1 \tag{37}$$

Knowing this, Germany chooses $z_1$ so as to minimise German costs:

$$\min_{z_1} \quad (z_1 - z_0^*)^2 + z_1^2 + 4Vf^2 z_1^2$$

and sets:

$$z_1 = \frac{z_0^*}{2(1+2Vf^2)} \tag{38}$$

From equations (28) and (35) Germany prefers this outcome to free floating if:

$$z_1^2 + (z_1 - z_0^*)^2 + 4\ Vf^2 z_1^2 \ < \ s^2 + (s - z_0^*)^2 + V\ [fs - \bar{z}_0/4]^2 \tag{39}$$

where $z_1$ is given by (38) and s is the value of $z_1^*$ given by (35). In order to interpret this condition, consider the case where $z_0^*$ tends to zero. Then (39) tends to :

$$0 < s^2 + (s - z_0^*)^2 + v\ [fs - \bar{z}_0/4]^2$$

18. Similar descriptions of the EMS are proposed by Giavazzi and Giovannini (1986a) (1986b).

With a small initial inflation problem, Germany will be close to its most prefered situation under $EMS_1$ when it sets $z_1$ and France uses capital controls. Can France be induced to play this game? France welfare costs are simply $L=z_0^2$ under this version of $EMS_1$, while under free floating (with capital controls) both countries experience period one inflation of $x_1=f\overset{+}{z}_1^2$, where $\overset{+}{z}_1$ is the value given in equation (28). Hence France will opt for the arrangement for sufficiently high values of inflation costs V.[19] [20]

Of course, this is merely an example of a situation where $EMS_1$ may be chosen over free floating under capital controls. It is not possible to assert that it will generally be the case. Intuitively, what happens is that the EMS leads to the choice of a particular value for $\bar{z}_1$, and if this value happens to be "right" the EMS Pareto-dominates free floating. Using capital controls permits to modify the particular value of $\bar{z}_1$ associated with the EMS regime and opens up the possibility that a more favourable $\bar{z}_1$ will emerge. But it can go the other way round as well, so that we have no general result to offer at this stage. In this section we have begun to set out how to properly integrate the two previous sections, the roles of an EMS and of capital controls.

## 7. CONCLUSIONS

We began with the determination to model cooperation as the outcome of hard and realistic bargaining not as some spontaneous outbreak of benevolence and goodwill. Similarly, we were keen to develop a dynamic model with forward looking behaviour, and to be able to give an analytical treatment of the issues. Although there is a price to be paid, particularly the truncation of

19. Note that this argument does not apply in reverse. If France sets $z_1$ and Germany $x_1$, then French inflation will no longer be zero under $EMS_1$ since France, with $z_0 \neq 0$, will not set $z_1 = 0$.

20. Even if Germany cannot induce France to join $EMS_1$ when $z_1 = 0$, some slightly higher $z_1$ may be sufficient to induce France to join.

time after only a few periods, we believe that our structure has been rich enough to demonstrate the fruits of research in analytical models.

Our primary concern has been to focus on clear, alternative regimes within each of which behaviour then evolves according to the rules of the game. The equilibrium regime is one on which the two countries can reach mutual agreement. Within this framework we have been able to contrast the effect of capital controls and exchange rate rules. It is worth restating that the clarity of our results is very special. Only when the two countries have identical structures and preferences can we be sure that the system neatly factorises into independent (+) and (-) systems; in general this will not hold. Even so, our stylised model is capable of replicating many of the tensions which underlie French and German policy making in practice.

One final remark. We have seen that the incentives to form an EMS are sensitive to the initial conditions inherited by potential member countries. This raises the intriguing possibility that an EMS formed to fight inflation might disintegrate once unemployment, not inflation, was the main concern, especially if both the success on inflation and the extent of the unemployment problem were unanticipated at the date the bargain took place to hammer out the operating rules of the EMS.

## APPENDIX A: Model Solution

### 1. Free float

Equation (13) gives the period two values as a function of period one state variables $z_1$ and $z_1^*$. The whole system is solved separately for the (+) and (-) variables. Hence (13) becomes:

$$\overset{+}{r}_2 = \overset{+}{z}_1/b(1+\theta) \qquad\qquad \bar{r}_2 = k\bar{z}_1$$

$$\overset{+}{x}_2 = 0 \qquad\qquad \bar{x}_2 = -\,2gk\bar{z}_1 \tag{A1}$$

$$q_2 = -\,k\bar{z}_1$$

Next, we express $\overset{+}{z}_1$ and $\bar{z}_1$ as a function of the policy variables $r_1$ and $r_1^*$, or rather $\overset{+}{r}_1$ and $\bar{r}_1$, as well as the initial conditions $\overset{+}{z}_0$, $\bar{z}_0$. From interest parity (1) and (A1) we have:

$$q_1 = -\,k\bar{z}_1 - \bar{r}_1 \tag{A2}$$

Using (2), (A2) and $\bar{y}_1 = \bar{z}_1 - \bar{z}_0$

$$\overset{+}{y}_1 = -\,b(1+\theta)\overset{+}{r}_1 \qquad\qquad \bar{y}_1 = \frac{\bar{r}_1+2ak^2\bar{z}_0}{k(1+2ak)} \tag{A3}$$

Hence with $\overset{+}{z}_1 = \overset{+}{z}_0 + \overset{+}{y}_1$ and $\bar{z}_1 = \bar{z}_0 + \bar{y}_1$:

$$\overset{+}{z}_1 = -b(1+\theta)\overset{+}{r}_1 + \overset{+}{z}_0 \qquad\qquad \bar{z}_1 = -\,\frac{\bar{r}_1 - k\bar{z}_0}{k(1+2ak)} \tag{A4}$$

Finally (6′) gives:

$$\overset{+}{x}_1 = -bf(1+\theta)\overset{+}{r}_1 + f\overset{+}{z}_0 \qquad \bar{x}_1 = -\,\frac{(f+4agk^2)\bar{r}_1-(f-2gk)k\bar{z}_0}{k(1+2ak)} \tag{A5}$$

The first order conditions are obtained by noting that

$$x_1 = \tfrac{1}{2}(\overset{+}{x}_1 + \bar{x}_1), \quad x_1^* = \tfrac{1}{2}(\overset{+}{x}_1 - \bar{x}_1), \text{ etc...}$$

so that $\dfrac{\partial x_1}{\partial r_1} = \tfrac{1}{2}\left(\dfrac{\partial \overset{+}{x}_1}{\partial \overset{+}{r}_1} + \dfrac{\partial \bar{x}_1}{\partial \bar{r}_1}\right) = \dfrac{\partial x_1^*}{\partial r_1^*}$, etc...

The Nash solution is obtained by maximizing L in (8) with respect to $r_1$, holding $r_1^*$ constant, and $L^*$ with respect to $r_1^*$, holding $r_1$ constant. It yields (14) in the text.

Adding and differencing (14), and using (A1) and (A5), we get:

$$\overset{+}{z}_1 = \frac{\overset{+}{z}_0}{2+fH} \qquad \bar{z}_1 = \frac{1 + 2gkH}{2(1+gkJ) + (f+4agk^2)H}\,\bar{z}_0 \tag{A6}$$

$$\overset{+}{x}_1 = \frac{f\overset{+}{z}_0}{2+fH} \qquad \bar{x}_1 = \frac{f+4agk^2 - 4gk(1+gkJ)}{2(1+gkJ) + (f+4agk^2)H}\,\bar{z}_0 \tag{A7}$$

2. <u>$EMS_1$</u>

Applying (17) between period two and three, and noting the steady state conditions $q_3 = \pi_3 = \pi_3^* = 0$, obviously we get $q_2 = 0$. Then (18) and (A1) yield:

$$\bar{z}_1 = 0 \qquad \bar{r}_2 = 0 \qquad \overset{+}{r}_2 = \overset{+}{z}_1/b(1+\theta) \tag{A8}$$

The behaviour of the (-) system is governed by the restriction $\bar{z}_1 = 0$. Imposing this restriction in (A4) gives the policy restriction:

$$\bar{r}_1 = k\bar{z}_0 \tag{A9}$$

As $q_2 = 0$, (1) shows that $q_1 = -\bar{r}_1$. Differentiation of (6′) yields $\bar{x}_1 = 2gq_1$. Thus (A9) shows that the $EMS_1$ leaves no room for policy choices within the (-) system.

The behaviour of the (+) system leaves one degree of freedom for policy. Using (2) and (7), we have:

$$\overset{+}{z}_1 = \overset{+}{z}_0 - b(1+\theta)\overset{+}{r}_1 \tag{A10}$$

which confirms that choosing $\overset{+}{r}_1$ is equivalent to choosing $\overset{+}{z}_1$. The rest of the (+) system is determined by (6′) and (7) as shown in (20).

3. EMS$_2$

The restriction (17) now applies to periods one and two and gives $q_2 - q_1 = \pi_2^* - \pi_2$. Using (1), (3), (5) and (7), and recalling that $\bar{z}_2 = 0$ from (11), the implication of EMS$_2$ can be written as:

$$(1+\theta)\bar{r}_1 = c\bar{z}_1 - \bar{x}_1 \tag{A11}$$

This restriction fully determines the (-) system. To see this, note that the evolution of the system in period two is the same as in the free float regime, so that (13) applies. In particular we have $q_2 = -k\bar{z}_1$ so, by (1):

$$q_1 = -k\bar{z}_1 - \bar{r}_1 \tag{A12}$$

Differentiation of (2) and (7) further yields:

$$\bar{r}_1 = -k(1+2ak)\bar{z}_1 + k\bar{z}_0 \tag{A13}$$

Eliminating $q_1$, $\bar{r}_1$ and $\bar{x}_1$ in (6′), (A11) and (A13) finally gives (22). Because $d < 1$, $E > 0$. That $E < 1$ is clear upon inspection.

The (+) system remains described by the same equation as the free float regime as there is no additional restrictions.

## APPENDIX B: Indifference Maps

1 - Using only the structural equations (A1)-(A7) under free floating, the system can be represented in $(\overset{+}{z}_1, \bar{z}_1)$ space as:

$$\overset{+}{x}_2 = 0 \qquad \bar{x}_2 = -2gk\bar{z}_1 \qquad \overset{+}{x}_1 = f\overset{+}{z}_1 \qquad \bar{x}_1 = (f+4agk^2)\bar{z}_1 - 2gk\bar{z}_0$$
$$\overset{+}{y}_2 = -\overset{+}{z}_1 \qquad \bar{y}_2 = -\bar{z}_1 \qquad \overset{+}{y}_1 = \overset{+}{z}_1 - \overset{+}{z}_0 \qquad \bar{y}_1 = \bar{z}_1 - \bar{z}_0 \tag{B1}$$

Using $x = \frac{1}{2}(\overset{+}{x}+\bar{x})$, $x^* = \frac{1}{2}(\overset{+}{x}-\bar{x})$ etc, and inserting these values into the cost functions in equation (8) we obtain $L(\overset{+}{z}_1, \bar{z}_1)$ and $L^*(\overset{+}{z}_1, \bar{z}_1)$. Both are quadratics and indifference curves are ellipses. To calculate the centre of the French ellipse, we simply set the partial derivatives of L(.) equal to zero. Similarly, for Germany. This yields equation (23). Letting C denote the French bliss point and $C^*$ the German, C must lie northwest of $C^*$ as (23) implies:

$$\overset{+}{z}_1(C) - \overset{+}{z}_1(C^*) = D^{-1}(2af+2g(1-2ak)^2 + 4g^2vfk)\bar{z}_0 \quad > \quad 0$$
$$\bar{z}_1(C) - \bar{z}_1(C^*) = D^{-1}(-2af\overset{+}{z}_0) \quad < \quad 0 \tag{B2}$$

2 - Points C and $C^*$ lie on the Nash reaction functions under free floating. Note that the latter makes conjectures that the other country's <u>interest rate</u> is exogenous. Hence the simplest way to derive the reaction functions is simply to use the French part of (14) plus (B1) to calculate the French reaction function in $(\overset{+}{z}_1, \bar{z}_1)$ space and the German part of (14) plus (B1) to calculate the German reaction function. This yields:

$$\text{France: } \overset{+}{z}_1 = -[1+(2+fh)^{-1}(2gk(J+2akH))]\bar{z}_1 + (2+fH)^{-1}[\overset{+}{z}_0+(1+gkH)\bar{z}_0]$$
$$\text{Germany: } \overset{+}{z}_1 = [1+(2+fH)^{-1}(2gk(J+2akH))]\bar{z}_1 + (2+fH)^{-1}[\overset{+}{z}_0-(1+gkH)\bar{z}_0] \tag{B3}$$

The intersection of these two reaction functions gives the Nash equilibrium under free floating, and is shown in equation (24).

3 - The tilt of the ellipses can be found as follows. First we note that the French and German ellipses are symmetric vis a vis the vertical direction. So we only consider a French ellipse. Its slope is found to be:

$$\partial \overset{+}{z}_1 / \partial \bar{z}_1 \Big|_{L=ct} = - \frac{V(f+4Vagk^2)x_1 + 2Vg^2k^2\bar{z}_1 + 2z_1 - z_0}{V\lambda x_1 + 2z_1 - z_0} \tag{B4}$$

Let us consider the special case where its center is on the vertical axis. By (23) this happens when $2gk\bar{z}_0 = fz_0$. We consider next the particular ellipse which goes through the origin (so $\overset{+}{z}_1 = \bar{z}_1 = 0$, $\overset{+}{x}_1 = 0$ and $\bar{x}_1 = -gk\bar{z}_0$). Then by (B4) the slope is unambiguously negative.

4 - The role of V is seen by letting it go to infinity. Then the two centres and the Nash point become:

C: $\overset{+}{z}_1 = (2gk/f)\bar{z}_0$ ; $\bar{z}_1 = 0$

$C^*$: $\overset{+}{z}_1 = -(2gk/f)\bar{z}_0$ ; $\bar{z}_1 = 0$

N: $\overset{+}{z}_1 = 0$ ; $\bar{z}_1 = A\bar{z}_0$

with $A = 2gkh/[hf + 2gk(j+2akh)] > 0$
where $j = J/V > 0$, $h = H/V > 0$

Whether $EMS_1$ is the solution depends upon whether the origin then falls within the shaded area on figure 1: there is no obvious interpretation for this restriction. As V is reduced, inspection of (23) shows that $C^*$ moves north-east, N north and C away from the vertical axis. These results are shown on figure 2(a).

5 - The role of $\overset{+}{z}_0$ is studied by considering the case $\overset{+}{z}_0 = 0$. Then we have $\overset{+}{z}_1(C) = -\overset{+}{z}_1(C^*)$, $\bar{z}_1(C) = \bar{z}_1(C^*)$, and $\overset{+}{z}_1(N) = 0$. When $\overset{+}{z}_0$ increases, holding $\bar{z}_0$ constant, inspection of (B3) makes it clear that both reaction function shift upward by the same amount as N, which moves up vertically. The shift of C follows from (23):

C: $$\frac{\partial \overset{+}{z}_1}{\partial \overset{+}{z}_0} = [af + g(1+4\ a^2k^2)]/D > 0$$

$$\frac{\partial \bar{z}_1}{\partial \overset{+}{z}_0} = -\ af/D < 0$$

For $C^*$, the change in $\overset{+}{z}_1$ is identical, for $\bar{z}_1$ it is the opposite. These results are presented on figure 2(b).

6 - When $\bar{z}_0 = 0$, the $EMS_2$ line coincides with the $EMS_1$ line along the vertical axis. We also have $\overset{+}{z}_1(C) = \overset{+}{z}_1(C^*)$, $\bar{z}_1(C) = -\ \bar{z}_1(C^*) < 0$ and $\bar{z}_1(N) = 0$. When $\bar{z}_0$ increases, holding $\overset{+}{z}_0$ constant, the two reaction lines move rightward by the same amount (see (B3)), so does the Nash point. The French bliss point C moves as follows:

$$\frac{\partial \overset{+}{z}_1}{\partial \bar{z}_0} = [af + g(1-2ak)^2 + 2Vg^2fk]/D > 0$$

$$\frac{\partial \bar{z}_1}{\partial \bar{z}_0} = a\ (4gk-f)/D \gtrless 0$$

For $C^*$, the change in $\overset{+}{z}_1$ is opposite, identical for $\bar{z}_1$. This is shown on figure B1(c). The arrows marked (1) correspond to the case $4gk > f$, the arrows marked (2) to $4gk < f$.

## APPENDIX C: Period One under Free Floating when Capital Controls are Anticipated in Period Two.

With controls in period two, $q_2 = 0$, hence $x_2 = x_2^* = 0$ (see (6′) and (11)). Hence, by (1), $q_1 = -\bar{r}_1 - \bar{t}$ where $\bar{t}$ is the difference between the French and the German tax rates. Then from (2) and (7):

$$\bar{y}_1 = -\bar{r}_1/k - 2a\bar{t} \tag{C1}$$

Using (6′) and (7) we obtain:

$$\bar{x}_1 = -\frac{f+2gk}{k}\bar{r}_1 - (2af+2g)\bar{t} + f\bar{z}_0 \tag{C2}$$

Obviously the (+) system is not affected by period one controls, so this part of (A3) to (A5) applies.

There are now three instruments, $r_1$, $r_1^*$ and $\bar{t}$. In our linear system, with quadratic loss functions, we can treat separately the choice of $r_1$ and $r_1^*$ from that of $\bar{t}$. Therefore, conditional on $\bar{t}$, France uses $r_1$ to minimise $L_1 = Vx_1^2 + y_1^2 + y_2^2$ since $x_2 = 0$, and Germany chooses $r_1^*$ to minimise $L_1^* = Vx_1^{*2} + y_1^{*2} + y_2^{*2}$. The first-order conditions are:

$$Nx_1 + y_1 - y_2 = 0 \qquad\qquad Nx_1^* + y_1^* - y_2^* = 0 \tag{C3}$$

where: $N = V(f+\frac{g}{a+b})$

Differentiating these conditions, and using (C1) and (C2) we get:

$$\begin{aligned}\bar{z}_1 &= \frac{1+2gkN}{2+N(f++2gk)}\bar{z}_0 + \frac{2gN(1-2ak)}{2+N(f+2gk)}\bar{t}\\ \bar{x}_1 &= \frac{f-2gk}{2+N(f+2gk)}\bar{z}_0 + \frac{4g(1-2ak)}{2+N(f+2gk)}\bar{t}\end{aligned} \tag{C4}$$

Summing up these conditions, we obtain (28) in the text which is independent of $\bar{t}$.

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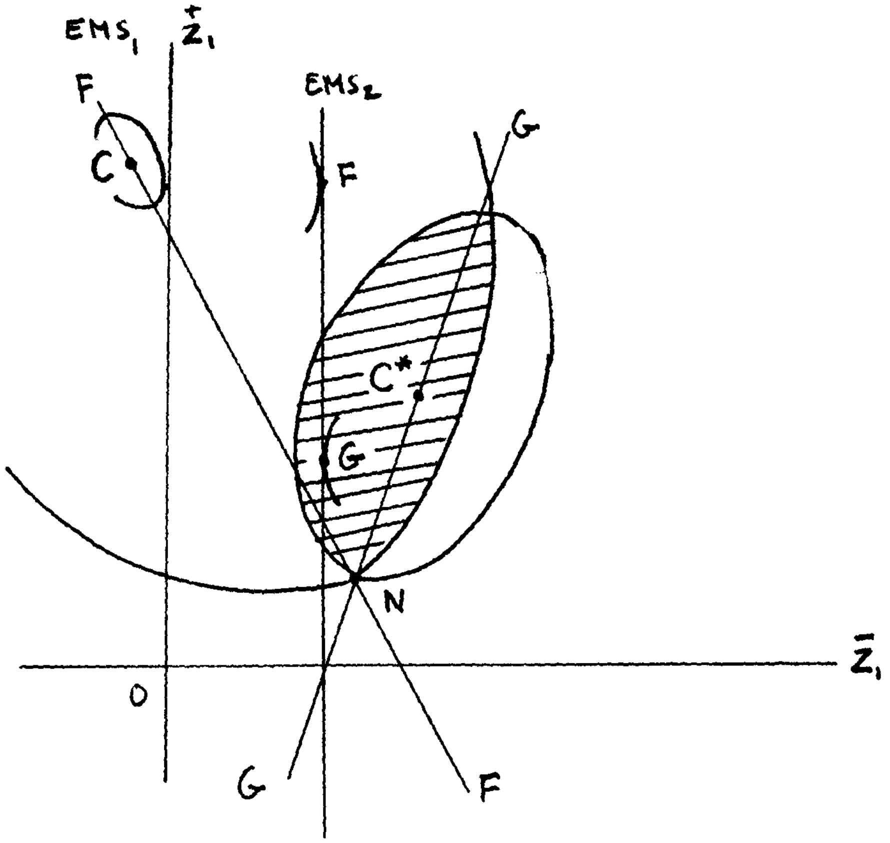



Figure 1(a)

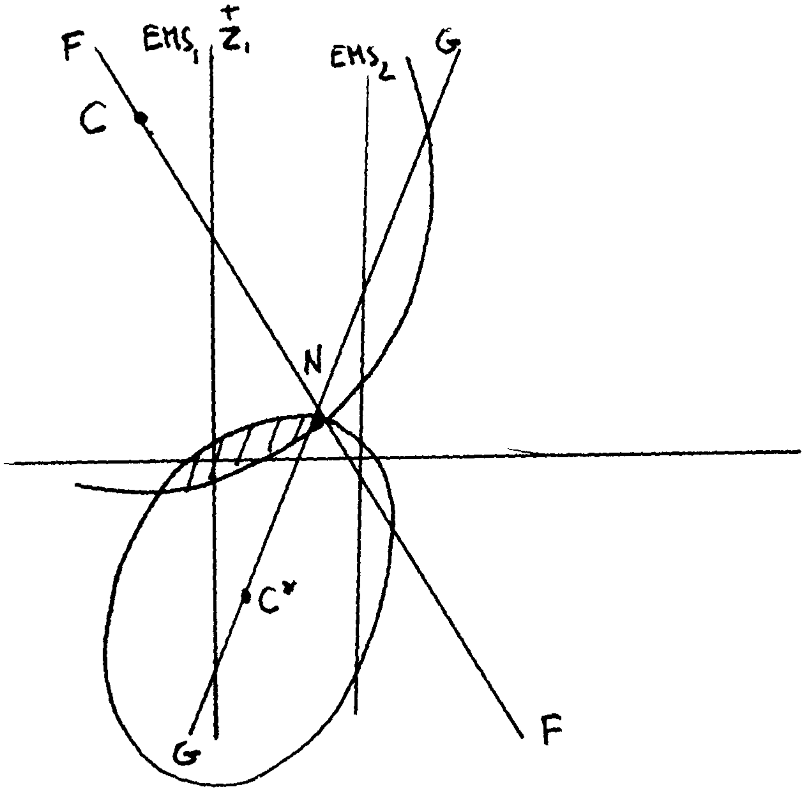
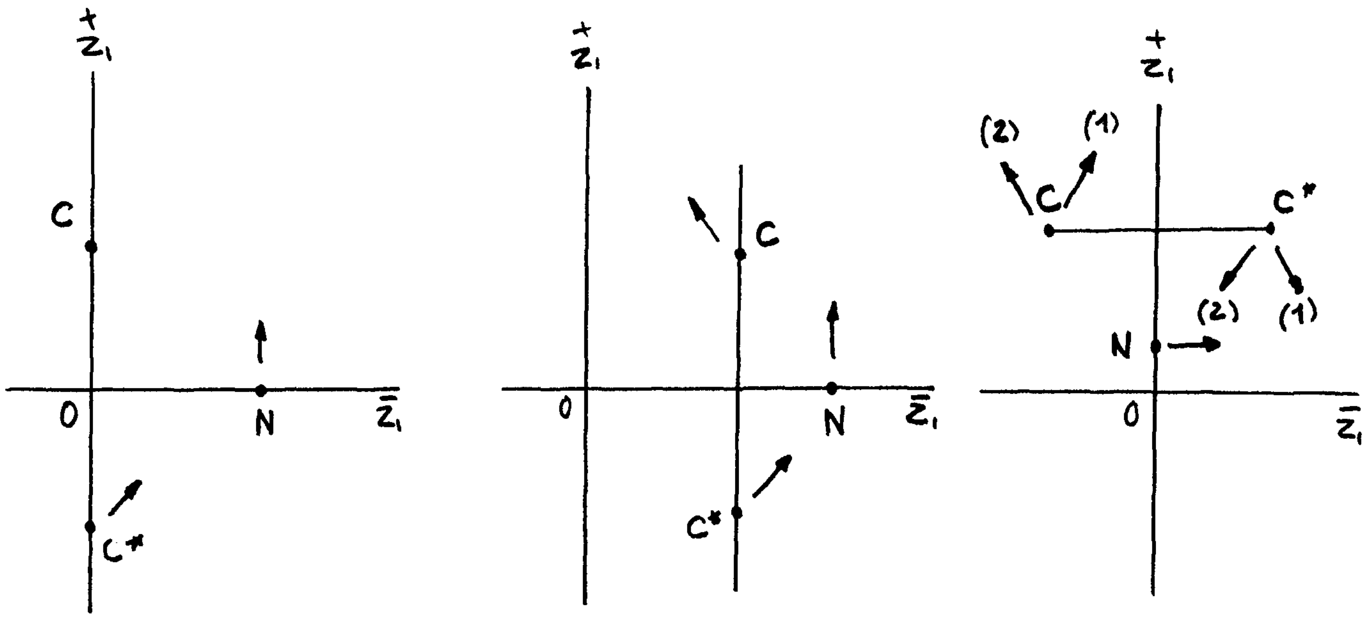



Figure 1(b)




$V = \infty$ $\qquad$ $\overset{+}{z}_0 = 0$ $\qquad$ $\bar{z}_0 = 0$

(1): $4gk > f$
(2): $4gk < f$

(a) $\qquad$ (b) $\qquad$ (c)

Figure 2

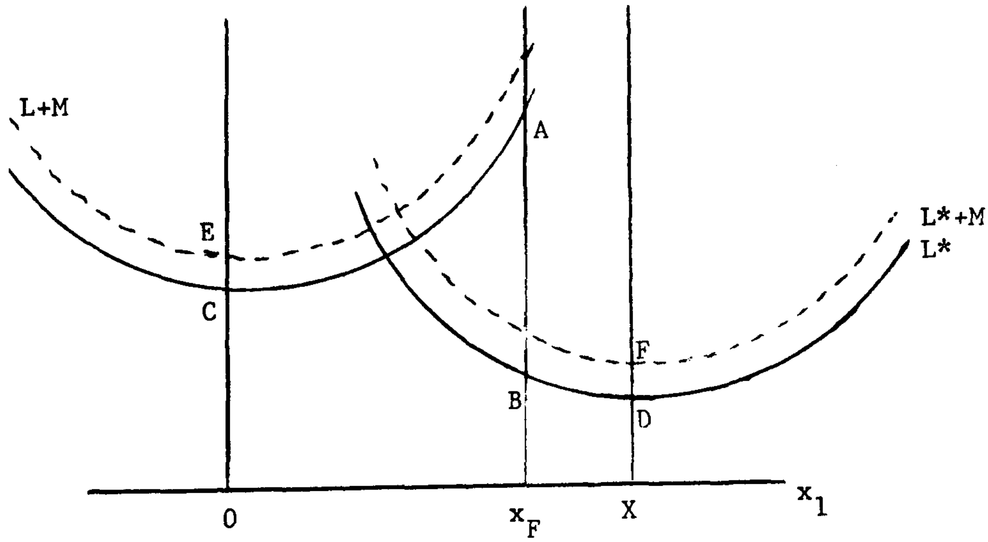



Figure 3. The Period One Control Game

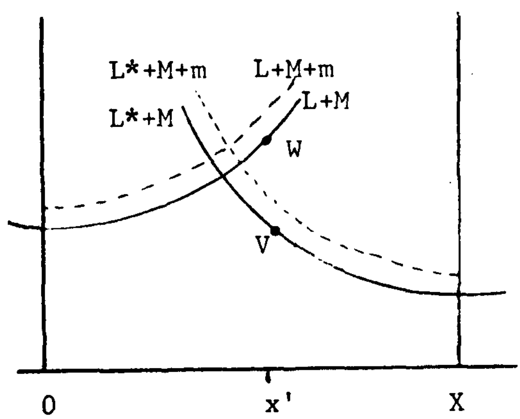



Figure 4. Equilibrium in the Retaliation Game

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