

Coordination, Cooperation, Contagion and Currency Crises¹

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Abstract

We analyze the effect of trade competition, international coordination and cooperation on currency crises. To do this, we present a micro-founded model where governments have an incentive to devalue to increase the national market share in a monopolistically competitive sector. Currency crises generated by self-fulfilling expectations are possible because private agents demand high wages when they expect a devaluation. This decreases the competitiveness and profits of national firms and induces the government to devalue. We show that the more important trade competition, the more likely self-fulfilling speculative crises are and the larger the set of multiple equilibria. Coordination decreases the possibility of simultaneous self-fulfilling speculative crises in the region and reduces the set of multiple equilibria. However, regional coordination, even though welfare improving, makes countries more dependent on other countries' fundamentals so that it may induce more contagion. Cooperation further reduces the set of multiple equilibria with currency crises.

Keywords

Contagion, coordination, cooperation, fixed exchange rates, exchange rate crisis, trade competition

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I. Introduction

Recent currency crises, such as the 1992-1993 EMS crisis, the crash of the Mexican Peso in 1994 and its Tequila effect on other countries as well as the Asian crisis have involved several countries in the same geographical region. Most recently, the Asian crisis broke out in Thailand in May 1997, but spread rapidly to Malaysia, the Philippines, Indonesia and South Korea. In the European case, contagion was also important as the crisis hit five countries (Finland, the UK, Italy, Sweden and Norway) in its first year. By 1993 all countries except Netherlands had to widen the band of fluctuation with the DM. The attack on the peso was itself followed by attacks on several Latin American countries.

Despite the fact that currency crises typically involve several countries that fix their currencies either to the dollar or to the DM, existing models of currency crisis look at the problem in a two country framework where the actions of the country that pegs its currency are key¹. This is the case of models of the “first generation” type (Krugman [1979]), where the crisis comes with a run on the Central Bank’s reserves, because speculators understand that monetary authorities conduct a policy inconsistent with the fixed parity. This is also the case with “second generation” models (Obstfeld [1991]), which consider devaluation as an intentional decision of a government, that weighs advantages and disadvantages: the cost of opting out of the fixed exchange rate system is primarily considered as a political cost; as for the cost of staying in, it can be modeled as high interest rates² or as unemployment³.

As argued by Glick and Rose [1998], “from the perspective of most speculative attack models, it is hard to understand why currency crisis tend to be regional’. They argue that trade linkages should be first among the suspects for explaining regional contagion of currency crises and give strong empirical support to this channel using five different crises. Eichengreen, Rose and Wyplosz [1996], in an empirical study using thirty years of panel data from twenty industrialized countries, also conclude in favor of a stronger explanatory power of international trade linkages than of macroeconomic similarities. Even though not modeled explicitly by these authors, the role of trade linkages is that in the presence of price rigidities a devaluation brings a short term competitive advantage to the country that devalues and therefore increases the cost for trade partners not to devalue.

The existence of these spillovers raises the issue of international cooperation: if governments take into account the negative externalities of devaluation on other countries, it might be easier to stop the snowball, perhaps even before it starts. Actually, some steps had been taken before the outbreak of the Asian crisis towards increased monetary cooperation

between East Asian countries⁴. As prophesied by Bayoumi and Eichengreen [1996], these unassuming measures however proved ‘insufficient to repel an all-out attack on an Asian currency comparable to the Mexican or ERM crises’.

In this paper we analyze the role of trade linkages in currency crises. To do this, we present a three country model that builds on three separate literatures: 1) the literature on international monetary cooperation, especially Canzoneri and Henderson [1991]’s theoretical approach, 2) the literature on currency crises, or more precisely on the ‘escape clause’ approach of fixed exchange rate systems, 3) the micro-founded new open economy macroeconomics framework initiated by Obstfeld and Rogoff [1995] and reviewed by Lane [1998]. Our model corresponds to a three-player, sequential game. The players involved are private agents and the two governments that unilaterally peg their currency to a third one. The two governments have an incentive to devalue because countries compete on a monopolistically competitive good that they both export. Currency crises that are generated by self-fulfilling expectations are possible because private agents rationally demand high wages when they expect a devaluation. This decreases the competitiveness of national firms and induces the government to devalue. To our knowledge, this framework is the first attempt to introduce micro-foundations in models of devaluations with self-fulfilling expectations.

We show that even when in equilibrium devaluations do not give any short term competitive advantage, strong trade competition increases the likelihood of currency crises that are induced by self-fulfilling expectations and magnify regional instability by increasing the number of possible multiple equilibria. We also show that countries that export goods in monopolistic sectors are more prone to devaluation induced by self-fulfilling expectations than countries specialized in competitive sectors. This fits well with the fact that recent currency crises have hit mostly new industrialized countries rather than countries, such as African ones in the CFA zone, that export mostly raw products.

We analyze the role of international coordination and cooperation in this context. Coordination is defined as in Canzoneri and Henderson [1991]: governments coordinate on the best Nash equilibrium so that it does not require any commitment technology. Policy-makers do not give up sovereignty in this case and all that is required is that they meet and coordinate on a good non cooperative solution, for example in a regional forum. Because multiple equilibria due to self-fulfilling expectations are a natural outcome in this type of setup, the question of the feasibility of coordination on a specific equilibrium is a natural and important one. Cooperation is more demanding as it implies that governments maximize a joint welfare function. It therefore requires a commitment technology in the form of a supra-

national institution that enforces the agreement. Both coordination and cooperation decrease but do not eliminate the possibility of simultaneous self-fulfilling speculative crises and reduce instability by limiting the set of multiple equilibria. However, regional coordination, even though welfare improving, makes countries more dependent on other countries' fundamentals so that it may induce more contagion: if one country of the region is more likely to devalue because of a worsening of its fundamentals, this increases the possibility of a currency crisis in both countries because it reduces the credibility of coordination between the two countries.

Our paper is related to Buitier, Corsetti and Pesenti [1995] and [1998] who analyze the beneficial role of cooperation in the context of exchange rate crises in Europe. It differs in several dimensions. First, our model is based on micro-foundations. Second, in their model, a devaluation in one country is assumed to induce a positive effect on other countries that have not devalued. Third, expectations of the private sector play no role in their analysis of international cooperation so that the currency crisis they obtain are not due to self-fulfilling expectations and multiple equilibria do not arise. Finally, because they do not allow for the possibility of multiple equilibria induced by self-fulfilling expectations, they do not analyze coordination but only look at the most demanding form of cooperation where governments minimize a joint loss function. Another related paper is Corsetti, Pesenti, Roubini and Tille (1998), who present a micro based model of competitive devaluations. Our model is different in that it analyzes the strategic interactions that lead to possible currency crises whereas their paper studies the different welfare consequences of a devaluation. In contrast to their model, self-fulfilling expectations of private agents play a crucial role in our analysis.

We present a simple micro-founded model of competitive devaluations in section II. We then solve and analyze the equilibria of the game in Section III. Section IV concludes.

II. The basic framework

The model corresponds to a three-country world: country A , country B and country Z . Country Z represents a large country to which countries A and B have pegged their currencies. To fix ideas, we will call the currency of country Z the dollar. We will assume that country Z is large compared to A and B and does not act strategically. Country Z plays two roles: 1) it issues the numeraire currency; 2) we want to differentiate competition between countries that fix their exchange rate to a third one (A and B) and competition between a fixing country (A or B) and the country to which it pegs its currency (Z).

As in Obstfeld and Rogoff (1995 and 1996), we introduce a monopolistically competitive sector. Countries A and B are both fully specialized in different varieties of this sector. In contrast to Obstfeld and Rogoff, these varieties are only exported. There are n_A , n_B , and n_Z firms (respectively in countries A, B and Z) which each produce a different variety. The world demand for a composite intermediate good made of the different varieties is exogenous and given by:

$$\bar{Y} = \left[\sum_{i=1}^{i=n_A} y_{A_i}^{1-1/\sigma} + \sum_{i=1}^{i=n_B} y_{B_i}^{1-1/\sigma} + \sum_{i=1}^{i=n_Z} y_{Z_i}^{1-1/\sigma} \right]^{\frac{1}{1-1/\sigma}} ; n_A + n_B + n_Z = N ; \sigma > 1 \quad (1)$$

where y_{Ai} represents the production of firm i in country A and σ is the elasticity of substitution between the different varieties. As the world demand for the composite good \bar{Y} increases, world trade increases for a given number of firms in the world. Hence, we focus our attention on an environment where countries A and B compete on the same third markets. This is consistent with the measure of trade linkage used by Glick and Rose (1998) who focus on competition on third markets rather than on direct bilateral trade. Eichengreen, Rose and Wyplosz (1996) also note that “Finland’s devaluation in august 1992 was widely regarded as having had negative repercussions for Sweden, not so much because of direct trade between the two countries but because their exporters competed on the same third markets.”

In countries A and B, agents (whose numbers are respectively n_A and n_B) share the same preferences: they derive utility from consumption of good x imported from country Z and disutility from effort in labor measured by l . The utility function of a representative agent is linear and given by:

$$U_i = x_i - \gamma l_i - \delta_i C_i , i = A, B \quad (2)$$

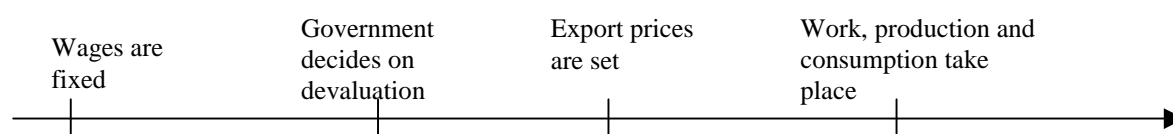
where γ measures the relative disutility from work. We have also added a fixed cost C_i , $i = A, B$, in the case the government devalues. $\delta = 0$ if the government decides not to devalue and 1 if the government devalues. We interpret this cost as arising from the disruption of the economic activity in case of devaluation. In models of speculative attacks (see Obstfeld, 1996, Jeanne, 1997) this cost is borne by the government that loses credibility in the case of a devaluation. In our framework, we may interpret the credibility loss as implying a higher interest rate on foreign debt which itself generates higher taxes for private agents.

The budget constraint of a representative agent in A is given by the following equation (a symmetric one holds for the representative agent in B):

$$w_A l_A + t_A = e_A x_A \quad (3)$$

This budget constraint is given in terms of the local currency. A representative agent derives income from labor paid at wage w_A in country A and from a government transfer t_A which will be detailed later. The imported good x is paid at the nominal exchange rate e_A between country A and Z . We normalize and fix the price of good x in Z to one and we assume zero inflation in that country during the period. For a consumer in A , the cost of the imported good in local currency will therefore be either $e_A = 1$ if the fixed exchange rate is maintained or $e_A = d$ if the government in A decides to devalue at the exogenous rate d^5 .

The timing of decisions by the different players is given below. First, wages paid in local currency are set. They can not be changed afterwards. This is the source of rigidity in the model which, together with the assumption that wages can not be paid in dollars, explains why devaluations may be optimally chosen. Second, each government decides whether to devalue or not. Third, monopolistic firms set their prices to maximize profits. Demands for exported goods are then realized, as well as demands for imported goods. Finally, production and consumption take place.



There are two sources of inefficiency in this set-up. First, the good market is monopolistic so that production will be too low. Second, in an application of double marginalization, the labor market is also monopolistic because there is a single union per firm. This will push the wage rate too high.

The price elasticity for a single producer of the export good is $-\sigma$, so that we get the usual price rule (expressed in local currency) for a monopolistic producer who maximizes profits: $p = w\beta\sigma/(\sigma-1)$ where β is the labor requirement (common to all three countries) in the export sector.

We assume that there is a single union per firm. The monopolistic union in each firm knows the price rule above and the labor demand function when it decides on the wage. It therefore takes into account that the wage elasticity of production and labor is $-\sigma$. Its objective is to maximize the expected utility of the representative worker in the union subject to the budget constraint. This means that the union has to form expectations on the exchange rate policy. Each union is small (there are as many unions as firms) so that it does not internalize the fact that it influences the exchange rate policy nor the transfer (see below) when it chooses

nominal wages. Appendix 1 shows that the wage rate is the mark-up over the marginal disutility from effort in labor:

$$w_i = \frac{\sigma}{\sigma-1} \gamma e_i^e, \quad i = A, B \quad (4)$$

where e_i^e is the expected exchange rate between country i and country Z . We want the real wage in all situations, even out of equilibrium, to be higher than the marginal disutility of work. This imposes a parameter restriction such that the elasticity of substitution is small enough: $\sigma/(\sigma-1) > d^6$. In country Z , the wage rate is determined in the same manner but because we fix the price of x in that country to 1, the wage rate is simply $\gamma\sigma/(\sigma-1)$. Depending on whether a devaluation is expected or not in the countries that fix their exchange rate to the dollar, the nominal wages will be high or low. Hence, the expectation on the exchange rate will influence the marginal cost of monopolistic firms and therefore their price decision:

$$p_i = \beta \gamma \left(\frac{\sigma}{\sigma-1} \right)^2 e_i^e, \quad i = A, B \text{ in local currency and } \beta \gamma \left(\frac{\sigma}{\sigma-1} \right)^2 \frac{e_i^e}{e_i}, \quad i = A, B \text{ in dollars. An}$$

unexpected devaluation therefore decreases this price. Using the monopolistic price rule, equation (4), and the fact that all firms in a specific country are symmetric and face the same exchange rate, we get that the demand and the production levels of representative monopolistic firms in each country that pegs its currency to the dollar are (see appendix 2 for a more detailed derivation):

$$y_A = \bar{Y} \left[n_A + n_B \left(\frac{e_A^e}{e_A} \frac{e_B^e}{e_B} \right)^{\sigma-1} + n_Z \left(\frac{e_A^e}{e_A} \right)^{\sigma-1} \right]^{\frac{\sigma}{1-\sigma}} \quad (5)$$

$$y_B = \bar{Y} \left[n_B + n_A \left(\frac{e_B^e}{e_B} \frac{e_A^e}{e_A} \right)^{\sigma-1} + n_Z \left(\frac{e_B^e}{e_B} \right)^{\sigma-1} \right]^{\frac{\sigma}{1-\sigma}}$$

Under our perfect foresight assumption, we can see already that fully expected devaluations will have no real impact as in this case, the devaluation is exactly compensated by a higher wage and higher marginal cost. However, suppose that private agents in country A and B expect no devaluation ($e_A^e = e_B^e = 1$), so that nominal wages are low, then a surprise devaluation ($e_A = d > 1$), will increase production of monopolistic firms in A and lower production in monopolistic firms in B . Hence, from that point of view, a surprise devaluation is a “beggar-thy-neighbor” policy in this model. These equations illustrate the spillovers at play in the model. The dependence of production in A on the exchange rate policy of B can

increase in two ways: first, if world trade \bar{Y} expands and second if n_B , the number of firms in B competing on third markets, increases.

Note also, that when the private sector in country A expects a devaluation, ($e_A^e = d > 1$), then a policy of no devaluation ($e_A = 1$) is costly as national production decreases. This explains why self-fulfilling expectations will occur in this setup.

The monopolistic profits of firms are taxed and fully redistributed to the private agents in the form of a lump-sum transfer. Given that the number of firms and the number of agents are identical, the transfer to the representative agent is the profit of the representative firm:

$$t_i = \beta \gamma e_i^e y_i \frac{\sigma}{(\sigma - 1)^2}, i = A, B \quad (6)$$

with y_i given by equation (5). It is easy to check that profits of firms and therefore the per-capita transfer decrease with exchange rate expectations and increase with the exchange rate of the country. Because each small union does not internalize the impact of its wage decision on the aggregate transfer, nominal wages will be too high.

Taking into account this transfer in the consumer budget constraint, the equilibrium utility of a representative agent is given by:

$$U_i = \beta \gamma \left[\frac{e_i^e}{e_i} \left(\frac{\sigma}{\sigma - 1} \right)^2 - 1 \right] y_i - \delta_i C_i, i = A, B \quad (7)$$

where y_i is given by equation (5) and the term in bracket is always positive due to the parameter restriction: $\sigma/(\sigma - 1) > d$. On top of the standard devaluation cost C_i , this equation shows that an unexpected devaluation has two welfare consequences. On the one hand it reduces the purchasing power of consumers by increasing the price of imported goods: the term $\frac{e_i^e}{e_i}$ in the bracket takes the value $1/d$ in the case of an unexpected devaluation. On the

other hand, as shown in equations (5) and (6), it increases domestic production, profits and income. The problem of each government will be to set the exchange rate to 1 (no devaluation) or d (devaluation), taking exchange rate expectations and the exchange rate policy of the other country as given, in order to maximize the utility of the representative consumer.

The absence of a non traded local good implies that the consumption price index is the exchange rate and this simplifies greatly the analysis. If such a good was introduced, the wage rate would depend on the expected price index that would comprise both local and imported goods. Hence, an expected devaluation would lead to an increase in nominal wages

of lower magnitude. From that point of view, self-fulfilling expectations would be less important in generating currency crises. On the other hand, because the purchasing power cost of a devaluation is lower in the presence of local goods, this should lead to a stronger incentive to devalue.

III. Rationally expected Nash equilibria

Because we assume that country Z does not play strategically *vis-à-vis* countries A and B , the relevant players are the following: unions, the government of country A and the government of country B . There are two games: the first one takes place between the private sector on the one hand and the governments on the other hand, and the second one between the two governments. Because unions, when they form expectations on a devaluation, base them on the expected result of the game between the governments, we solve the game by backward induction. We will first analyze the equilibrium of the game between the governments before looking at the private sector's expectations. The equilibrium in this game depends on the institutional setting that governs the relations between the governments of A and B , which we assume is known by the private sector when it sets its expectations:

- no coordination: governments play Nash; a Nash equilibrium is such that no government has a unilateral incentive to deviate. If, in the policy game, several equilibria are possible, governments choose the one expected by private agents.
- coordination: governments coordinate on the Nash equilibrium that Pareto-dominates all Nash equilibria. We adopt here the terminology of Canzoneri & Henderson [1991] (p.4): coordination refers to the way policymakers settle on one solution out of several in a non-cooperative game. It corresponds to a relatively weak requirement: when the governments coordinate with each other, they do not need to trust each other, they just need to consult with each other to simultaneously move to a specific Nash equilibrium. Once they coordinate on an outcome, none of them has any incentive neither to deviate unilaterally from it nor to deviate in a coordinated manner from it. This stability makes coordination credible to private agents.
- cooperation: the governments choose the outcome that maximizes the sum of the utility levels of representative consumers. Cooperation imposes solidarity between both governments. Since it may lead to outcomes which prove not unilaterally stable, because they are not Nash equilibria, cooperation may not appear credible to private agents. We will therefore consider cooperative equilibria as benchmark equilibria. We will need to

assume their credibility, through a commitment technology that may involve some institutional structure for instance.

We assume that unions know the nature of the game governments play: no coordination, coordination or cooperation. We assume moreover that unions and governments have full information on all parameter values. Since no uncertainty exists, rational expectations equilibria correspond to perfect foresight equilibria.

III.1. No coordination

Suppose that private agents expect none of the governments to devalue: $e_A^e = e_B^e = 1$. Governments then play this specific game. If parameters are such that neither A nor B has an incentive to deviate, then $e_A^e = e_B^e = e_A = e_B = 1$ is a rationally expected Nash equilibrium. This will be the case when:

$$U_A(e_A^e = e_B^e = e_A = e_B = 1) \geq U_A(e_A^e = e_B^e = e_B = 1; e_A = d)$$

and

$$U_B(e_A^e = e_B^e = e_A = e_B = 1) \geq U_B(e_A^e = e_B^e = e_A = 1; e_B = d)$$

Rational private agents may indeed expect $e_A^e = e_B^e = 1$ when these two inequalities are satisfied: they correspond to $C_A \geq \bar{C}_A^1$ and $C_B \geq \bar{C}_B^1$. These threshold values are given in appendix 3. In **diagram 1**, the equilibria have been illustrated in relation to the value of parameters.

Now, suppose that private agents expect both governments to devalue: $e_A^e = e_B^e = d$. The governments, in the policy stage, then play a different game. If parameters are such that:

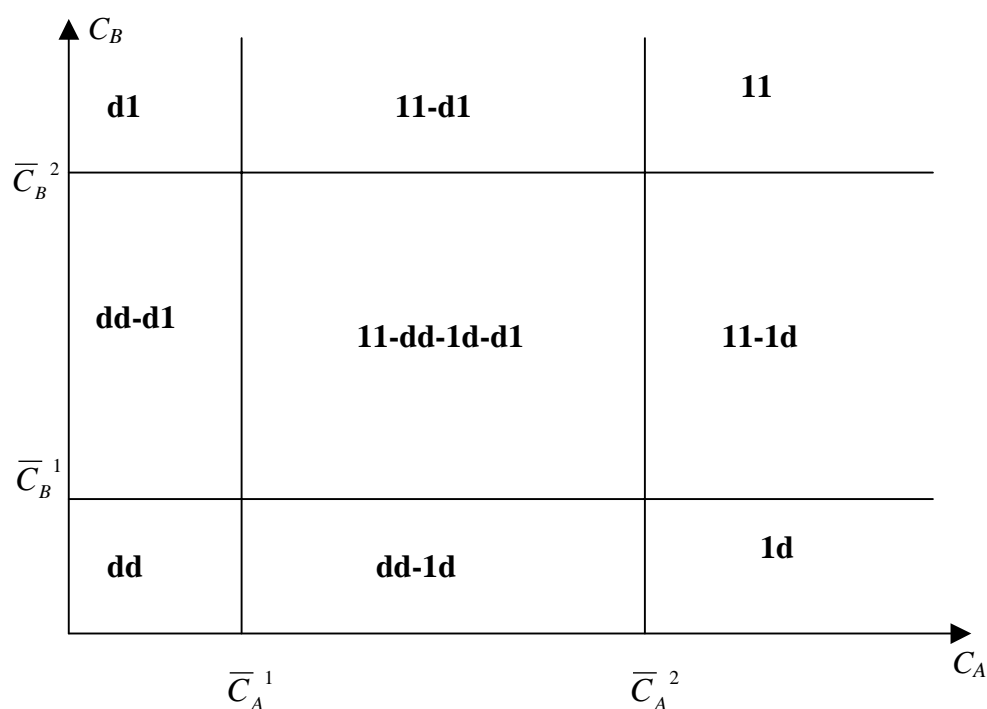
$$U_A(e_A^e = e_B^e = e_A = e_B = d) \geq U_A(e_A^e = e_B^e = e_B = d; e_A = 1)$$

and

$$U_B(e_A^e = e_B^e = e_A = e_B = d) \geq U_B(e_A^e = e_B^e = e_A = d; e_B = 1)$$

then $e_A = e_B = d$ is a rationally expected Nash equilibrium. Accordingly, in **diagram 1**, this equilibrium exists for parameters such that $C_A \leq \bar{C}_A^2$ and $C_B \leq \bar{C}_B^2$. Hence, the possibility of multiple equilibria arises in the middle rectangle of **diagram 1**. The existence of asymmetric equilibria, $e_A = 1, e_B = d$ and $e_A = d, e_B = 1$ is checked through a similar strategy.

Diagram 1⁷ The game's equilibria, when the governments do not coordinate with each other.



We can show analytically that $\bar{C}_A^2 > \bar{C}_A^1$ and $\bar{C}_B^2 > \bar{C}_B^1$ when $\bar{C}_A^1 > 0$, $\bar{C}_B^1 > 0$ and when d is sufficiently small (see appendix 4). Numerical simulations did not lead to any example where this would not be the case for high values of d , as long as \bar{C}_A^1 and \bar{C}_B^1 are positive.

The area of maximum instability is given in the middle square where all equilibria are possible due to self-fulfilling expectations. The intuition for the possibility of self-fulfilling expectations and devaluation when governments do not coordinate should be clear by now. If agents in country A expect a devaluation, then they ask for high nominal wages. In this case, if the government does not devalue, monopolistic firms of the country lose competitiveness and income decreases. If the fixed cost of devaluation is not too high (below the threshold \bar{C}_i^2 , $i = A, B$), then devaluation is an equilibrium. When the cost of devaluation is very low in both countries (below the threshold \bar{C}_i^1 , $i = A, B$), then the only equilibrium is that both countries devalue simultaneously. This is because in this case, the temptation to engage in competitive devaluation (even if private agents did not expect such a devaluation) is very high. This equilibrium would be eliminated if the labor market was perfectly competitive.

We can analyse the effect of the competitive structure of the industry by looking at the impact of an increase in the world number of firms N in the industry on the threshold values in **diagram 1**. To simplify the exercise we look at the effect of an increase of N on the

threshold values in the case where $n_A = n_B = n_Z = 1/3 N$ so as to keep the relative level of competition between countries symmetric. It is easy to check then that: $\frac{\partial \bar{C}_i^1}{\partial N} < 0$; $\frac{\partial \bar{C}_i^2}{\partial N} < 0$. Hence, countries specialized in more competitive industries (higher N implies more competition and less profits), are less subject to speculative devaluations. It is also easy to check that the area of maximum instability (all four possible equilibria) decreases with N , our measure of the degree of competition in the industry. The reason for these results is that as N rises, the potential profit gain of an unexpected devaluation decreases. This is recognized by private agents who adjust their expectations accordingly. In the same vein, when the elasticity of substitution tends to infinity, the goods market becomes perfectly competitive, and $\bar{C}_i^2, i = A, B$, tends to zero so that governments never devalue. This fits quite well with the observation that non industrialized countries such as African countries of the CFA zone that export mostly raw products have had little experience with attacks on their fixed exchange rate. The attacks have been mostly concentrated on new industrialized countries.

Note that trade spillovers have an important impact on the possibility of devaluations and of self-fulfilling expectations. An increase in the world demand and trade of the composite good \bar{Y} increases both threshold values for both countries. This implies that the set of parameters for which both countries devalue simultaneously expands, and that the set of parameters for which no country devalues narrows. Note also that as \bar{Y} increases, the difference between \bar{C}_i^2 and $\bar{C}_i^1, i = A, B$, increases so that the middle square of maximum instability with self-fulfilling expectations expands. Even though in equilibrium devaluations have no real impact because they are fully expected given our perfect foresight assumption, their potential impact out of equilibrium explains the increased incentive to devalue (and therefore the increased possibility of self-fulfilling expected devaluations) when trade increases. With more trade, the potential gain of an unexpected unilateral devaluation is higher as utility increases with profits that themselves increase with production and exports. Because this potential gain is fully expected by private agents, trade magnifies the possibility of devaluations induced by self-fulfilling expectations.

Evaluated at $n_A = n_B = n_Z = 1/3 N$ and holding N and n_Z constant, we can also show that: $\frac{\partial \bar{C}_A^1}{\partial n_B} > 0$; $\frac{\partial \bar{C}_A^2}{\partial n_B} > 0$ with symmetric results for the threshold levels in country B . A higher number of competitors in B increases the incentive of country A to devalue and

expands the set of multiple equilibria with all four equilibria. The intuition is that a higher number of competitors in B increases the importance of trade spillovers for A .

One can also check that when n_B and n_Z are sufficiently small compared to n_A , \bar{C}_A^2 becomes negative so that A does not devalue whatever B does. In this case, trade spillovers are small in the sense that country A does not compete much with country B on third markets. This also says that large countries are less prone to currency crises than small ones.

III.2. Coordination

Because devaluations in equilibrium have no real effect on output as they are fully expected and because of the fixed cost of devaluation, the equilibrium where no government devalues always Pareto-dominates the equilibrium where one or both governments devalue. Hence, in the case of multiple equilibria, coordination on the Nash equilibrium with no devaluation can improve welfare. We want here to determine under which circumstances such a coordination is feasible.

Suppose that private agents expect both governments to devalue: $e_A^e = e_B^e = d$. If parameters are such that $C_A \leq \bar{C}_A^2$ and $C_B \leq \bar{C}_B^2$ then the equilibrium where both governments devalue is a Nash equilibrium. However, if:

$$U_A(e_A^e = e_B^e = d; e_A = e_B = 1) \geq U_A(e_A^e = e_B^e = d; e_B = 1; e_A = d)$$

and

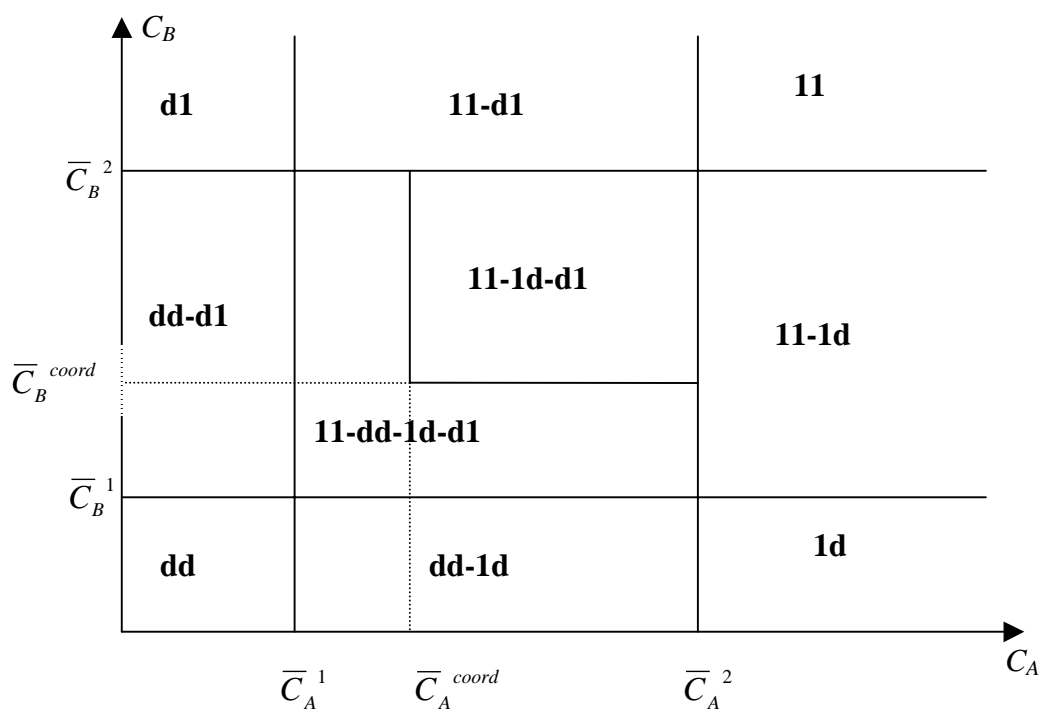
$$U_B(e_A^e = e_B^e = d; e_A = e_B = 1) \geq U_B(e_A^e = e_B^e = d; e_A = 1; e_B = d)$$

then even if agents expected both countries to devalue, governments could, for this set of parameters, coordinate on the Nash equilibrium where they jointly decide not to devalue. In this case, governments will choose to coordinate on this equilibrium because it can be checked that it Pareto dominates the one with simultaneous devaluation. None of the governments has any incentive to do so unilaterally though and this is the reason why coordination is required. The coordinated equilibrium with no devaluation is credible in the sense that no country has any incentive to devalue, neither unilaterally nor jointly.

The two above inequalities correspond to $C_A \geq \bar{C}_A^{coord}$ and $C_B \geq \bar{C}_B^{coord}$, with \bar{C}_A^{coord} and \bar{C}_B^{coord} defined in appendix 3. Therefore, when $\bar{C}_A^{coord} \leq C_A \leq \bar{C}_A^2$ and $\bar{C}_B^{coord} \leq C_B \leq \bar{C}_B^2$, the governments coordinate on changing their strategies and thus play $e_A = e_B = 1$ rather than $e_A = e_B = d$. Agents accordingly change their expectations. Situations in which agents do not

expect simultaneous devaluations lead to results similar to the no coordination case. All possible equilibria are illustrated on **diagram 2**.

Diagram 2 The game's equilibria, when the governments coordinate with each other⁹.



As shown in **diagram 2**, coordination reduces but does not eliminate the set of parameters where self-fulfilling expectations of devaluations in both countries are equilibria. However, it does not reduce the set of parameters for which a devaluation in one country only is an equilibrium so that its impact is only in situations when private agents expect both countries to devalue. Trade competition between the two countries explains the possible difference between coordination and no coordination. If for example country A does not compete with country B ($n_B = 0$), then it is easy to check that $\bar{C}_A^2 = \bar{C}_A^{coord}$ so that coordination with B is useless.

Note that coordination, whose role is to eliminate the worse possible equilibrium, is feasible and useful especially when countries are sufficiently similar and when the devaluation cost in both countries is sufficiently high relative to the potential devaluation gain. Otherwise, the equilibrium where no country devalues cannot be a Nash equilibrium when agents expect both countries to devalue as one country at least will have an incentive to deviate and devalue. In this case, coordination on the no devaluation equilibrium is not

sustainable. In other words, an announcement by both governments that they will not devalue when nominal wages are high is no longer credible.

This also illustrates a channel of contagion of currency crises different of those usually identified. In **diagram 2**, it can be checked that if economic parameters in country *A* change so that C_A becomes less than \bar{C}_A^{coord} (either because C_A decreases or because \bar{C}_A^{coord} increases), then the possibility of a self-fulfilling currency crisis increases not only in country *A* but also in country *B*: when \bar{C}_A^{coord} increases, the area of equilibria (*11-1d-d1*) is reduced at the expense of the area of equilibria (*dd-11-1d-d1*). This change in the economic situation of country *A* makes coordination between the two countries more difficult to sustain and an announcement that governments coordinate on the no-devaluation equilibrium will not be credible in this sense. If private agents now expect both countries to devalue, the coordinated equilibrium where both countries decide not to devalue is no longer a Nash equilibrium. Country *A* will be induced to deviate and devalue. This itself induces country *B* to devalue. This channel of contagion is different from the classic one based on competitive devaluations, which is absent here as in equilibrium devaluation gives no benefit to the country even if the other country does not devalue. Here, contagion of the currency crisis comes from the fact that regional coordination becomes less credible in the eyes of private agents when fundamentals in one country are such that this country is more likely to suffer a currency crisis.

It illustrates the ambiguous effect that coordination has on the issue of regional contagion. Compared to no coordination, it reduces the possibility of simultaneous speculative crises in a region with important trade spillovers and in this sense is welfare improving. However, because the credibility of coordination itself is dependent on parameters of both countries, it introduces a new channel of contagion.

III.3. Cooperation

Cooperation between two countries of different size is difficult to analyze so we choose to restrict our attention to the case where the two countries are identical: $n_A = n_B$ and $C_A = C_B$ ¹⁰. As in Buiter, Corsetti and Pesenti [1995, 1998] we assume a national horizontal equity constraint, according to which no international agreement is enforceable unless countries that are identical *ex ante* end up having an identical level of welfare *ex post*. This excludes the possibility of a cooperative equilibrium where one country devalues and the other does not. Cooperation then implies that governments choose jointly the same exchange

rate policy that maximizes the utility of a common representative consumer. In effect, cooperation is identical to the case where the two countries form a monetary union.

Suppose that private agents expect the governments to cooperate on the no-devaluation equilibrium: $e_A^e = e_B^e = 1$. If parameters are such that:

$$\begin{aligned} U_A(e_A^e = e_B^e = e_A = e_B = 1) &= U_B(e_A^e = e_B^e = e_A = e_B = 1) \\ &\geq \\ U_A(e_A^e = e_B^e = 1; e_A = e_B = d) &= U_B(e_A^e = e_B^e = 1; e_A = e_B = d) \end{aligned}$$

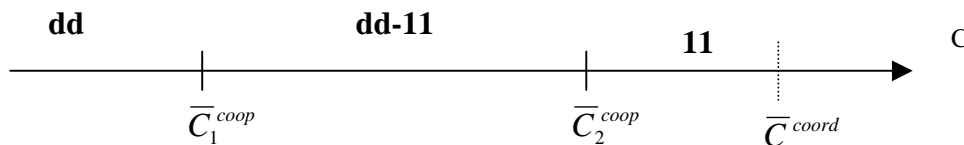
then $e_A^e = e_B^e = e_A = e_B = 1$ is a rationally expected cooperative equilibrium. Suppose on the contrary that private agents expect governments to cooperate on the devaluation equilibrium. If parameters are such that:

$$\begin{aligned} U_A(e_A^e = e_B^e = e_A = e_B = d) &= U_B(e_A^e = e_B^e = e_A = e_B = d) \\ &\geq \\ U_A(e_A^e = e_B^e = d; e_A = e_B = 1) &= U_B(e_A^e = e_B^e = d; e_A = e_B = 1) \end{aligned}$$

then $e_A = e_B = d$ is a rationally expected cooperative equilibrium. The first inequality corresponds to $C_A = C_B \geq \bar{C}_1^{coop}$. The second inequality corresponds to $C_A = C_B \leq \bar{C}_2^{coop}$. The values of \bar{C}_1^{coop} and \bar{C}_2^{coop} are given in appendix 3.

Diagram 3 shows that even though a devaluation has no real impact in equilibrium, cooperation between *A* and *B* is not enough to eliminate the possibility of self-fulfilling currency crisis. The reason is that, even though governments can commit to each other they still can not commit to private agents. Out of equilibrium, they can cooperate and surprise private agents through a devaluation and gain competitiveness relative to country *Z* firms. The equilibrium with devaluation is fully eliminated only when $n_Z = 0$. In this case, \bar{C}_2^{coop} is negative because governments in *A* and *B* have no incentive to devalue.

Diagram 3: The game equilibria when governments cooperate¹¹



It can be checked that for $n_A = n_B$, $\bar{C}_A^1 = \bar{C}_B^1 > \bar{C}_1^{coop}$ and that $\bar{C}_A^2 = \bar{C}_B^2 > \bar{C}_2^{coop}$. This implies that cooperation narrows the set of parameters for which both countries devalue and expands the set of parameters for which both countries decide not to devalue. Because \bar{C}_2^{coop} is lower

than $\bar{C}^{coord} = \bar{C}_A^{coord} = \bar{C}_B^{coord}$ (with $n_A = n_B$), cooperation reduces the set of parameters for which both countries may devalue and improves welfare relative to the coordination equilibrium. It is easy to see that when trade spillovers are eliminated for A (n_B tends to zero), then $\bar{C}_1^{coop} = \bar{C}_A^1$ and $\bar{C}_2^{coop} = \bar{C}_A^2 = \bar{C}_A^{coord}$ so that cooperation between A and B is useless.

Contrary to coordination, cooperation requires a strong commitment technology to be sustainable so that we view it mainly as a benchmark case. However, if we interpret the European integration process and the political institution building that goes with it as such a commitment device, we can analyze the impact of European monetary cooperation on contagion in this specific context.

IV. Conclusion

In this paper, we have asked two sets of questions. First, how do regional trade structures increase the instability of a fixed exchange rate regime and the probability that it collapses simultaneously in the region? The answer to this question is that the more trade competition between countries in a monopolistic sector, the more fragile fixed exchange rate regimes are. We have shown that this is the case even in a model where there is no real gain to a devaluation in equilibrium because the devaluation is perfectly expected by agents. The result is likely to be even stronger if we allow for the possibility of unexpected shocks that would lead to unexpected devaluations. Second, do coordination and cooperation reduce instability and contagion? We have shown that the answer to this second question is more ambiguous. Neither coordination nor cooperation eliminate the possibility of crises induced by self-fulfilling expectations. However, coordination and cooperation reduce the set of fundamental parameters for which simultaneous devaluations is an equilibrium and are therefore welfare improving. Both are stabilizing in the sense that they reduce the number of equilibria. Because multiple equilibria due to self-fulfilling expectations are a natural outcome of this type of model, the role of coordination on a specific equilibrium is important. In contrast to cooperation, coordination does not require a commitment technology, and should therefore be relatively easy. We have shown however that coordination reduces the possibility of simultaneous devaluations, at the cost of making each country's more dependent on the other's fundamentals.

References

- Bayoumi T. and B. Eichengreen [1996]: 'Is Asia an Optimum Currency Area ? Can it become one ? Regional, Global and Historical Perspectives on Asian Monetary Relations', paper presented at the *CEPII/AMUE/KDI conference* on exchange rate arrangements for East Asian countries, 14-16 November 1996, Seoul.
- Bensaid, B and O. Jeanne, [1997], "The Instability of Fixed Exchange Rate Systems when Raising the Nominal Interest Rate is Costly", *European Economic Review*, August, vol. 41, n° 8, 1489-1509.
- Buiter W., G. Corsetti and P. Pesenti [1995]: 'A Centre-Periphery Model of Monetary Coordination and Exchange Rate Crises', *CEPR Discussion Paper* No. 1201.
- [1998]: 'Financial Markets and European Monetary Cooperation', *Cambridge University Press*.
- Canzoneri M. and D. Henderson [1991]: 'Monetary Policy in Interdependent Economies, a Game-Theoretic Approach', *MIT Press*.
- Corsetti, G., P. Pesenti, N. Roubini, and C. Tille, [1998], "Competitive Devaluations: a Welfare-Based Approach", NBER working paper no. 6889.
- Drazen A, and P. Masson, [1994], "Credibility of Policies versus Credibility of Policymakers", *Quarterly Journal of Economics*, 109, 735-754.
- Eichengreen B., A. Rose and C. Wyplosz [1996]: 'Contagious Currency Crises', *CEPR Discussion Paper* No. 1453.
- Fraser B. [1995]: 'Central Bank Co-operation in the Asian Region', unpublished manuscript, *Reserve Bank of Australia*.
- Gerlach, S. and F. Smets, 1994, "Contagious Speculative Attacks", CEPR Discussion Paper no. 1055.
- Glick, R., and Rose, A., [1998]: 'Contagion and Trade: Why Are Currency Crises regional', CEPR Discussion Paper n° 1947.
- Jeanne O. [1995]: 'Models of Currency Crises: A Tentative Synthesis, with Special Reference to the 1992-1993 EMS Crises', *Mimeo*.
- [1997]: "Are Currency Crises Self-fulfilling? A Test", *Journal of International Economics*, vol. 43, 3 /4, 263-286.
- Krugman P. [1979]: 'A Model of Balance-of-Payments Crises', *Journal of Money, Credit and Banking* 11, 311-325.
- Lane P., [1998]: "The New Open Economy Macroeconomics: A Survey", CEPR Discussion Paper n° 2115.
- Loisel O. and P. Martin [1999]: "Coordination, Cooperation, Contagion and Currency Crises", CEPR Discussion Paper N° 2075.
- Masson, P. [1998]: "Contagion: Monsoonal Effects, Spillovers and Jumps Between Multiple Equilibria", IMF working paper 142.
- Obstfeld M. [1991]: 'Destabilizing Effects of Exchange Rate Escape Clauses', *Working Paper* No 3603 (NBER, Cambridge, MA).
- [1996]: 'Models of Currency Crises with Self-Fulfilling Features', *European Economic Review* 40, 1037-1048.
- Obstfeld M. and K. Rogoff, [1995], "Exchange Rate Dynamics Redux.", *Journal of Political Economy*, 103, 624-660.
- , [1996], *Foundations of International Macroeconomics*, MIT Press, Cambridge Mass.
- Ozkan, F.G. and A. Sutherland, 1994, "A Model of ERM Crisis", CEPR DP 879.

Appendix 1 : Wage determination

A monopolistic union i in country A chooses the wage rate w_i to maximize expected utility:

$$\frac{w_i l_i}{e_A^e} - \mathcal{N}_i - \delta_A C_A + \frac{t_A}{e_A^e}$$

taking into account the following perceived elasticities: $\frac{\partial y_i}{\partial l_i} \frac{l_i}{y_i} = \frac{\partial p_i}{\partial w_i} \frac{w_i}{p_i} = 1$; $\frac{\partial y_i}{\partial p_i} \frac{p_i}{y_i} = -\sigma$

Equation (4) in the text follows.

Appendix 2: Derivation of demand levels for each variety of the composite good

We solve a standard problem of cost minimization under the constraint of total demand given by equation (1). Denominated in dollar, the total cost is:

$$\sum_{i=1}^{i=n_A} \frac{p_i}{e_A} y_{A_i} + \sum_{i=1}^{i=n_B} \frac{p_i}{e_B} y_{B_i} + \sum_{i=1}^{i=n_Z} p_Z y_{Z_i}$$

This leads to the following demand level of a representative variety produced in country A :

$$y_A = \bar{Y} \left[n_A + n_B \left(\frac{p_A}{e_A} \frac{e_B}{p_B} \right)^{\sigma-1} + n_Z \left(\frac{p_A}{e_A} \frac{1}{p_Z} \right)^{\sigma-1} \right]^{\frac{\sigma}{1-\sigma}}$$

Using the price formula as a function of expectations on the exchange rate, we get equation (5) in the text. The demand levels for varieties produced in B are derived similarly.

Appendix 3: Values for the different threshold levels of the cost of devaluation

$$\bar{C}_A^1 = \beta \bar{\gamma} \bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 \frac{1}{d} - 1 \right] \left[n_A + n_B d^{1-\sigma} + n_Z d^{1-\sigma} \right]^{\frac{\sigma}{1-\sigma}} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] N^{\frac{\sigma}{1-\sigma}} \right\}$$

$$\bar{C}_B^1 = \beta \bar{\gamma} \bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 \frac{1}{d} - 1 \right] \left[n_B + n_A d^{1-\sigma} + n_Z d^{1-\sigma} \right]^{\frac{\sigma}{1-\sigma}} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] N^{\frac{\sigma}{1-\sigma}} \right\}$$

$$\bar{C}_A^2 = \beta \bar{\gamma} \bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] N^{\frac{\sigma}{1-\sigma}} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 d - 1 \right] \left[n_A + n_B d^{\sigma-1} + n_Z d^{\sigma-1} \right]^{\frac{\sigma}{1-\sigma}} \right\}$$

$$\bar{C}_B^2 = \beta \bar{\gamma} \bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] N^{\frac{\sigma}{1-\sigma}} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 d - 1 \right] \left[n_B + n_A d^{\sigma-1} + n_Z d^{\sigma-1} \right]^{\frac{\sigma}{1-\sigma}} \right\}$$

$$\bar{C}_A^{coord} = \beta \bar{\gamma} \bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] \left[n_A + n_B d^{1-\sigma} + n_Z \right]^{\frac{\sigma}{1-\sigma}} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 d - 1 \right] \left[n_A + n_B + n_Z d^{\sigma-1} \right]^{\frac{\sigma}{1-\sigma}} \right\}$$

$$\bar{C}_B^{coord} = \beta\gamma\bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] [n_B + n_A d^{1-\sigma} + n_Z]_{1-\sigma}^{\sigma} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 d - 1 \right] [n_A + n_B + n_Z d^{\sigma-1}]_{1-\sigma}^{\sigma} \right\}$$

$$\bar{C}_1^{coop} = \beta\gamma\bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 \frac{1}{d} - 1 \right] [n_A + n_B + n_Z d^{1-\sigma}]_{1-\sigma}^{\sigma} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] N_{1-\sigma}^{\sigma} \right\}$$

$$\bar{C}_2^{coop} = \beta\gamma\bar{Y} \left\{ \left[\left(\frac{\sigma}{\sigma-1} \right)^2 - 1 \right] N_{1-\sigma}^{\sigma} - \left[\left(\frac{\sigma}{\sigma-1} \right)^2 d - 1 \right] [n_A + n_B + n_Z d^{\sigma-1}]_{1-\sigma}^{\sigma} \right\}$$

Appendix 4: Derivation of conditions under which $0 \leq \bar{C}_A^1 \leq \bar{C}_A^{coord} \leq \bar{C}_A^2$.

Consider \bar{C}_A^1 , \bar{C}_A^{coord} and \bar{C}_A^2 as functions of parameter $d \geq 1$: $\bar{C}_A^1(d)$, $\bar{C}_A^{coord}(d)$ and $\bar{C}_A^2(d)$.

Then, it can be checked that:

$$\bar{C}_A^1(1) = \bar{C}_A^{coord}(1) = \bar{C}_A^2(1) = 0, \text{ and}$$

$$\bar{C}_A^1'(1) = \bar{C}_A^{coord}'(1) = \bar{C}_A^2'(1) = \frac{\beta\gamma\sigma\bar{Y}N_{1-\sigma}^{\sigma-1}}{(\sigma-1)^2} [-\sigma n_A + (\sigma-1)(n_B + n_Z)].$$

These equations imply that $\bar{C}_A^1(d)$ is positive in the neighborhood of $d=1$ if and only if

$$\frac{n_B + n_Z}{n_A} \geq \frac{\sigma}{\sigma-1}.$$

It can be also checked that :

$$\bar{C}_A^{coord}''(1) - \bar{C}_A^1''(1) = \frac{2\beta\gamma\sigma\bar{Y}N_{1-\sigma}^{\sigma-2}}{(\sigma-1)^2} [-\sigma n_A^2 + \sigma(\sigma-1)n_B^2 + \sigma(\sigma-2)n_A n_B + (\sigma-1)(4\sigma-1)n_A n_Z + \sigma(\sigma-1)n_B n_Z]$$

$$\bar{C}_A^2''(1) - \bar{C}_A^{coord}''(1) = \frac{2\beta\gamma\sigma\bar{Y}n_B N_{1-\sigma}^{\sigma-2}}{(\sigma-1)^2} [(\sigma^3 - (\sigma-1)^3)n_A - \sigma(\sigma-1)(n_B + n_Z)].$$

The first expression proves positive when $\frac{n_B + n_Z}{n_A} \geq \frac{\sigma}{\sigma-1}$, that is, when $\bar{C}_A^1(d)$ is positive in

the neighborhood of $d=1$. The second expression proves positive if and only if

$$\frac{n_B + n_Z}{n_A} \leq \frac{\sigma^3 - (\sigma-1)^3}{\sigma(\sigma-1)}. \text{ We know that: } \frac{\sigma}{\sigma-1} \leq \frac{\sigma^3 - (\sigma-1)^3}{\sigma(\sigma-1)}, \text{ as } \sigma \geq 1. \text{ Hence, if}$$

$$\frac{\sigma}{\sigma-1} \leq \frac{n_B + n_Z}{n_A} \leq \frac{\sigma^3 - (\sigma-1)^3}{\sigma(\sigma-1)}, \text{ then } \bar{C}_A^1''(1) \leq \bar{C}_A^{coord}''(1) \leq \bar{C}_A^2''(1). \text{ This implies, that when}$$

$$\frac{\sigma}{\sigma-1} \leq \frac{n_B + n_Z}{n_A} \leq \frac{\sigma^3 - (\sigma-1)^3}{\sigma(\sigma-1)} \text{ and for } d \text{ sufficiently close to one, then } 0 \leq \bar{C}_A^1 \leq \bar{C}_A^{coord} \leq \bar{C}_A^2.$$

Conditions under which $0 \leq \bar{C}_B^1 \leq \bar{C}_B^{coord} \leq \bar{C}_B^2$ are symmetric.

Diagram 2 on the effects of coordination corresponds to $0 \leq \bar{C}_A^1 \leq \bar{C}_A^{coord} \leq \bar{C}_A^2$ and

$$0 \leq \bar{C}_B^1 \leq \bar{C}_B^{coord} \leq \bar{C}_B^2. \text{ It is therefore valid for } \frac{\sigma}{\sigma-1} \leq \frac{n_B + n_Z}{n_A} \leq \frac{\sigma^3 - (\sigma-1)^3}{\sigma(\sigma-1)} \text{ and}$$

$$\frac{\sigma}{\sigma-1} \leq \frac{n_A + n_Z}{n_B} \leq \frac{\sigma^3 - (\sigma-1)^3}{\sigma(\sigma-1)}.$$

¹ Exceptions are Gerlach and Smets [1994], Masson [1998] and Buiters, Corsetti and Pesenti [1995] and [1998]

² See for example Obstfeld [1994] or Ozkan and Sutherland [1994].

³ See for example Bensaid and Jeanne [1994] or Drazen and Masson [1994]. For empirical evidence on the role of self-fulfilling speculation in currency crises, see Jeanne [1997].

⁴ We are referring to:

- November 1995 repurchase agreements between the Hong Kong Monetary Authority and the central banks of Australia, Malaysia, Indonesia and Thailand. These agreements, by allowing the central banks to borrow dollars from one another, enabled them to intervene more heavily at short notice.
- February 1996 support of the dollar/yen rate by Hong Kong and Singapore.
- March 1996 decision of the Bank of Japan, after that of Singapore and the Philippines' central banks, to sign the repurchase agreements.

Besides, Fraser [1995] may be read as a suggestion to go further, up to a common peg.

⁵ In the working paper version of this article, we analyze the case of endogenous devaluation rate in a simpler model.

⁶ This inequality corresponds to $w/e_i > \gamma$ in the case where $e_i^e = 1$ and $e_i = d$.

⁷ To save space, we note **II** the equilibrium where both countries stay in the fixed exchange rate, **dI** the equilibrium where country A devalues and B does not, etc.

⁸ We focus on the case where these inequalities are fulfilled. The conditions are given in appendix 4.

⁹ Under the same conditions as in **diagram 1**, we have that $\bar{C}_A^{coord} > \bar{C}_A^1$ and similarly for country B.

¹⁰ The working paper version of this article fully analyzes the case of cooperation. The conclusions are not very different from those presented here.

¹¹ Under the same conditions as in **diagram 1** (with $n_A = n_B$), we have $\bar{C}_1^{coop} < \bar{C}_2^{coop}$.