A MODEL OF CURRENCY CRISES WITH HETEROGENEOUS MARKET BELIEFS

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Abstract

This paper shows that the approach followed by Tamborini (2015) in analyzing and interpreting the euro area public debt crisis, based on the role played by agents characterized by heterogeneous market beliefs, can be applied also to the case of currency crises. By doing so, rather than considering the private sector as an atomistic player endowed with perfect information, and by considering a central bank that optimizes the amount of unsterilized inflow of foreign reserves in a Mundell-Fleming type speculative attack model, allows to explain the interest rates convex non-linearity that characterized, for example, a country like Italy during the 1992-93 EMS crisis.

JEL Classification: E58, F31, F41.

Keywords: Currency crises, speculative attacks, fixed exchange rates, heterogeneous agents

1. INTRODUCTION

Tamborini (2015) explains the recent euro area public debt crisis by considering the private sector as populated by agents characterized by heterogeneous market beliefs. He departs, then, from the assumption of a private sector characterized by perfect information and homogeneous beliefs and therefore acting like an atomistic player. He concludes that the larger is the primary surplus which is required for debt stabilization, the lower the degree of heterogeneity of agents' beliefs becomes, because the larger will be the fraction of market participants who will share the belief that the primary surplus required for stability is approaching its upper feasibility constraint, above which the stability of public debt cannot be assured anymore. In turn, such a shared belief of a more likely default increases the risk premium on public debt and, as a result, the interest rate to service it. This implies, then, that the closer the primary surplus gets to the expected upper limit, the more the interest rate will increase, so as to provide an explanation for the interest rate convex non-linearity identified - but not explained - by De Grauwe and Ji (2013a, 2013b).

This paper shows that the same approach can be applied also to currency crises, and in particular to the fundamentals-driven crisis that in 1992-93 affected some EMS countries, the most significant example of them being Italy, on which I will focus in this paper. [1] I do this by considering an optimizing central bank, which is assumed to decide what is the level of unsterilized inflow of foreign reserves to be let into the country in order to minimize its loss function.

As a matter of fact, the data show clearly that the period 1987-1992[2] was characterized by an inflow of only partially sterilized foreign reserves in Italy that on one

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[1] The crisis hitting France in July 1993 has been interpreted by Eichengreen *et al.* (1993) as having been caused by negative self-fulfilling expectations that would have been driven by the prescriptions contained in the Maastricht Treaty, rather than by diverging economic fundamentals. However, in spite of the good condition of the inflation rate and public finance variables, France was characterized by a high unemployment rate and - as it will be argued more in detail below - by a negative business cycle, that did not allow that country to accept the higher interest rates decided by the Bundesbank after German reunification.

[2] From its inception in 1979, the EMS went through different phases characterized by an increasing degree of institutional rigidity. The third phase, from 1987 to 1992, during which the exchange rate was kept fixed and no devaluation was allowed, and corresponding with the peak of popularity of credibility theory, was

hand supported the Italian economy and GDP (being directed mostly to finance the Italian public debt), but on the other hand determined a growth of the Italian monetary base. In turn, the latter induced a divergent core inflation rate with respect to the EMS monetary leader, namely Germany,[3] that appreciated in real terms the Italian lira and increased the Italian current account deficit, thereby making necessary at some point an exchange rate adjustment that re-established the initial conditions of country competitiveness.

The 1992-93 EMS speculative attack against the Italian lira, then, appears as related to a significant and clear divergence in the state of economic fundamentals.

Figure 1 shows the inflow of foreign reserves, together with the partial sterilization operated by the Bank of Italy by reducing the permanent holdings of government bonds when foreign capital was flowing into the country (the partial sterilization appears clearly by observing that over the period considered, the increase of the stock of foreign reserves exceeded significantly the reduction of permanent holding of government bonds by the Bank of Italy). Figure 1 also shows clearly how the temporary holdings of government bonds (*pronti c/ termine*) had to step in when foreign residents started withdrawing their funds when the fears of an exchange rate devaluation started growing.

Figure 2 shows the resulting inflationary divergence in Italy compared to Germany, and Figure 3 shows the growing Italian current account deficit over the period 1987-1992.

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explicitly considered as representing a 'new' EMS regime (Giavazzi and Spaventa, 1990).

[3] This mechanism is closely related to the one identified with the so-called Walters' critique (Walters, 1986), according to which the capital inflow from northern to southern EMS countries, by reducing the nominal interest rate with an unchanged inflation rate, would reduce the real interest rate, thereby heating up the economies of the latter countries, appreciating the real exchange rate and creating the conditions for a future current account imbalance and instability.

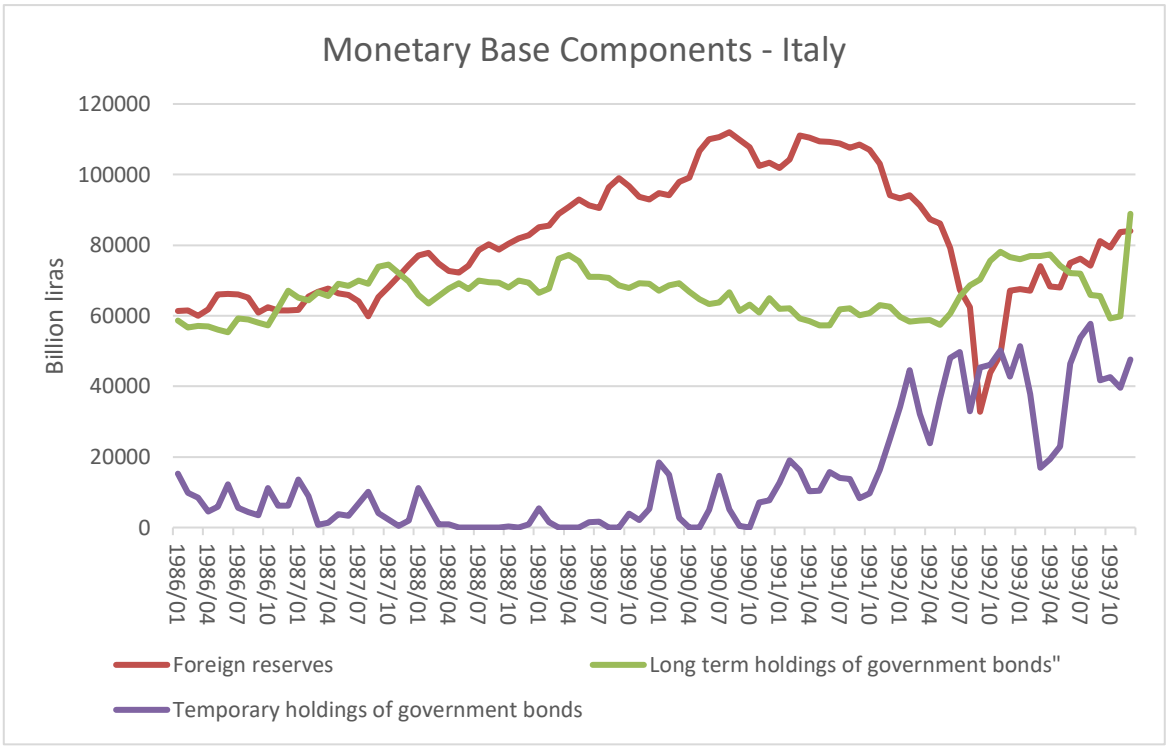

Figure 1: Monetary base components: Foreign reserves, long term and temporary holdings of government bonds. Source: BDS, Bank of Italy

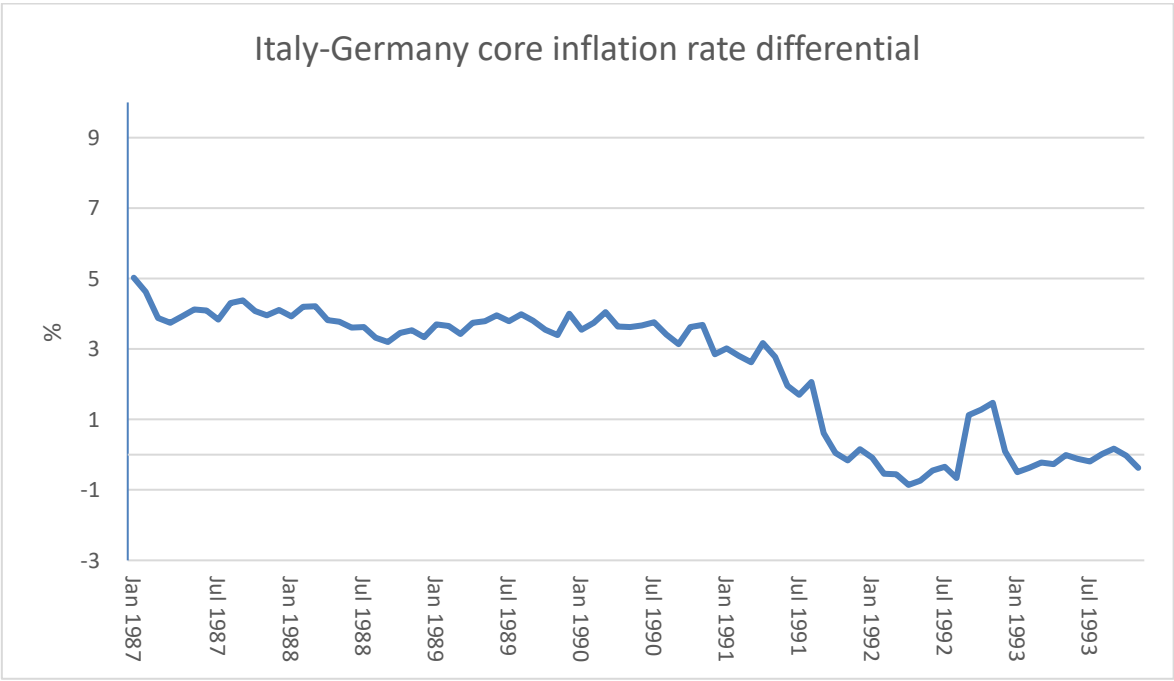

Figure 2: The Italy-Germany core inflation rate differential

Source: OECD, Main Economic Indicators

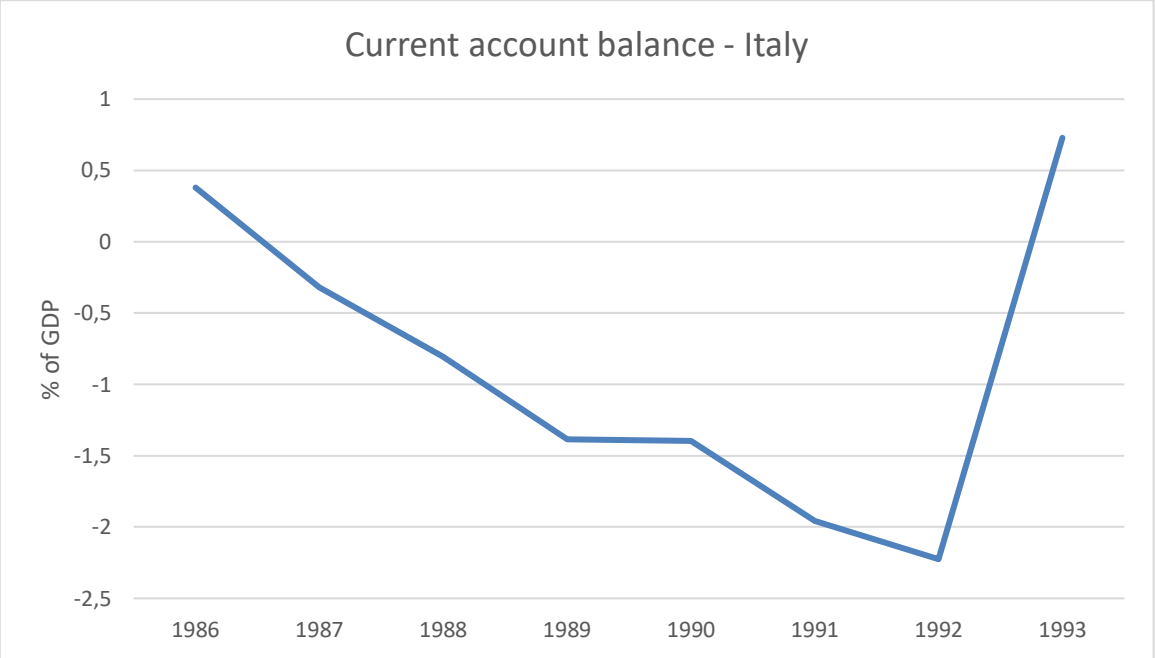

Figure 3. Current account balance, Italy
Source: World Bank, World Development Indicators

During the 1992-93 EMS crisis a convex non-linearity characterized the behavior of the interest rate of most of the countries whose currencies were under attack. The case of Italy[4], for example, one of the first countries whose currencies have been hit by speculation, is shown in Figure 4. The short term interest rate went up from 12.41% in May 1992, to 18.22% in September 1992. But a similar pattern can be found, for example, in Finland, Spain and Sweden, not to mention the case of Ireland, whose interest rate skyrocketed to 40% at the peak of the EMS crisis.[5]

[4] Although not a member of the EMS, Sweden was 'shadowing' the DM, and had been trying to resist the devaluation of the Swedish Krona (for just a few days its overnight rate reached clearly unsustainable levels well above 100%!).

[5] In the case of Ireland and Finland, the violence of the crisis was also due to the previous devaluation of the currencies of their commercial competitors, namely the UK and the former Soviet Union, that had just broken up.

Figure 4. Short term interest rates in Italy between 1987 and 1993

Source: OECD, Short-term interest rates (indicator). doi: 10.1787/2cc37d77-en.

This implies that the speculative attack gradually piled up over the time span of a few months and it became more and more predictable. These features, as I am going to argue more in detail below, are only partially captured by previous studies.

The model that I am proposing analyzes the consequences of the unsterilized inflow of foreign reserves (and therefore of a divergent inflation rate, as it will be discussed more in detail below) in a country belonging to a fixed exchange rate, like Italy in the EMS, by considering also the role of an optimizing central bank.

In addition to the inflationary divergence determined by capital inflows, the model that I am presenting allows also to account for the other elements that contributed to the EMS crisis.

The first of those additional causes is the destabilizing effect on partner countries resulting from the German refusal to honor the Basel-Nyborg agreement.[6]

[6] With the Basel-Nyborg agreement, signed in 1987, the Bundesbank promised to supply the (unlimited) amount of German Marks that would have been necessary to support the central banks of partner countries in the EMS

The destabilizing effects of an increase of the foreign interest rate, like the one decided by the Bundesbank after the German reunification because of the need to avoid the risk of inflation resulting from the adoption of the excessively expansionary 1-to-1 conversion rule between the East and the West German Mark, is the second additional aspect that the model allows to address.

Finally, this model allows to account for the effects of the negative expectational shocks resulting from the outcomes of both the Danish and the French referendum (respectively in June and September 1992), and for the effects of the negative business cycle shock hitting, at the beginning of the 1990s, an otherwise stable and economically sound country like France.

The paper is organized as follows. In section 2 I present a survey of the currency crises literature. In section 3 a heterogeneous agents' beliefs currency crisis model is presented. Section 4 analyses the effects of different changes in the private sector's reaction function. In section 5 the same analysis is conducted on the central bank's reaction function. Some concluding remarks close the paper.

2. A SURVEY OF THE CURRENCY CRISES LITERATURE

The Mundell-Fleming model and the interpretation provided by Padoa Schioppa (1987) of its conclusions suggest that in a fixed exchange rate regime with free capital mobility, domestic credit cannot be decided autonomously by the central bank. This is what the latter dubbed as 'inconsistent trinity'.

The mechanism through which this happens is well known: an excessive domestic credit creation induces a lowering of the interest rate that makes foreign bonds more attractive, given the unchanged, higher interest rate on them. The capital outflow would appreciate the foreign currency if the central bank did not intervene by buying the domestic one which is offered on the market, and by providing the foreign banknotes that the market

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fixed exchange rate agreement suffering a liquidity crisis. The fear that an excessive money creation would produce, one way or another, a higher inflation rate in Germany, however, induced later on the Bundesbank to disregard its commitment.

requests. By doing so, however, the level of foreign reserves that are available with the domestic central bank decreases, and if the latter keeps doing the same operation over and over again (for example by sterilizing the effects of the foreign exchange intervention on the domestic money supply), at some point foreign reserves will be exhausted and it will not be possible anymore to peg the exchange rate that, inevitably, will start fluctuating. So, while the Mundell-Fleming model concludes that monetary policy cannot be run independently by a country adhering to a fixed exchange rate system with free capital mobility, Padoa Schioppa's idea of an 'inconsistent trinity' concludes that fixed exchange rates cannot be maintained indefinitely in the case in which monetary policy is run independently and capital is allowed to move freely.

The Mundell-Fleming model is also at the roots of the literature on speculative attacks on fixed exchange rates: in the 'first generation' of fixed exchange rates speculative attacks models initiated by Krugman (1979) and simplified by Flood and Garber (1984), currency crises are caused by an exogenous divergent policy followed by the monetary authority in an environment in which capital is allowed to move freely. In these models, it is assumed that an *atomistic*, perfectly informed private sector is able to check whether money creation, which is also supposed to determine univocally the exchange rate, is consistent with the central bank's commitment to a fixed exchange rate. It is assumed to do so by comparing the latter with the 'shadow' exchange rate that would prevail in a free float regime. As soon as the state of the 'fundamental' variable represented by money creation (which in turn determines the behavior of foreign reserves), is expected to reach the critical value at which the 'shadow' exchange rate meets the fixed exchange rate, the private sector reacts in order to avoid the losses that would result from an unanticipated devaluation and the central bank is forced to abandon the parity in advance with respect to the natural exhaustion of foreign reserves. This is the novelty of Krugman's paper with respect to the conclusions of the Mundell-Fleming model: speculators cannot be held responsible for the fall of the fixed exchange rate system, but only for moving it up, since the fixed exchange rate will have to be abandoned due to the inconsistent expansionary monetary policy run by the central bank, in a situation in which capital is allowed to flow freely across countries. There exists, then, a unique critical level for the state of economic fundamentals below which everybody attacks the currency and above which nobody does it.

As a result, since currency markets are assumed to work efficiently and no currency attack would take place if only the monetary authority behaved in a disciplined manner, the

introduction of corrective economic policy measures (like the imposition of capital controls or of a transaction tax *à la* Tobin) would find no theoretical justification, in fact it would only prevent the correct and re-equilibrating functioning of the markets.[7]

Broner (2008), using Krugman's model, removes the assumption that all market participants are perfectly informed about the true state of economic fundamentals and allows for an uninformed share of market participants together with the complementary informed share. He shows that in such a case the shadow exchange rate may well exceed the value of the pegged one without causing a currency crisis. The crisis, then, will be sudden and unpredictable, as already the 'second generation' of currency crises models, had concluded.

In Obstfeld's contribution (Obstfeld, 1986), the seminal paper in the 'second generation' models, speculative attacks arise because of self-fulfilling expectations: given that the central bank's optimal policy is determined endogenously, speculators realize that if they attack the currency, the fixed exchange rate system will have to be abandoned, so that their prophecy becomes self-fulfilled. While some of these models seemed to prove that negative shifts of expectations may cause the abandonment of a fixed exchange rate system even in presence of sound fundamentals, either considering the role played by foreign reserves (Obstfeld, 1986) or referring to a central bank's costs-benefits analysis (Bensaid and Jeanne, 1997), other works re-established the role played by fundamentals even within this approach (Obstfeld, 1995, 1996). As a matter of fact, it should not be ignored, for example, that the private sector would have no convenience to attack a currency which is believed to be 'strong', even if it could easily defeat the defense of the central bank, since by doing so it would incur a loss.

Obstfeld (1995, 1996), then, proves the existence of three different regions for the state of economic fundamentals: (1) a region of instability, in which economic fundamentals are in such a bad state that the monetary authority finds the defense of the currency too costly, so that the currency will be devalued with certainty, even in the absence of an attack by

[7] The point that I am making is that if markets work efficiently and speculators are not responsible for the negative outcomes (because the latter result from the inconsistent behavior of the central bank, running a monetary expansion while being committed to keep the exchange rate fixed), then there is no theoretical justification for stopping speculation.

speculators; (2) a region of stability, in which economic fundamentals are in very good shape, so that no speculator has convenience to launch an attack on the currency and no devaluation takes place; and (3) the so called 'gray region', in which economic are neither too weak, so that the exchange rate will be attacked with certainty, nor too strong, so that they will never be attacked. In this region anything can happen: the exchange rate will be maintained if only 'few' speculators attack, while the central bank will be obliged to devalue if a 'high' proportion of speculators attack.[8] It should be noted that this approach implies that an attack against a currency will only be successful if fundamentals are 'weak'. Currency crises would not occur if the state of economic fundamentals were unequivocally strong.

This is a situation in which strategic complementarities play a role: speculators will only be successful in their attack if other speculators also attack, and this is where the multiplicity of equilibria arises. As a result, the same economic policy prescriptions as the ones resulting from the first approach should apply.

Even this approach that encompasses the first and the second generation models, however, leaves unexplained what determines the occurrence of the crisis, as we will further discuss below.

Morris and Shin (1998) take the situation characterized by common knowledge about the state of economic fundamentals as a starting point for their model, in order to show that economic fundamentals in the end identify unequivocally the unique timing of the speculative attack occurring within the intermediate "gray" area, in which fundamentals are neither too weak, so as to determine a speculative attack with certainty, nor too strong, so as to avoid it with certainty.

If we move from a situation of common knowledge of the state of economic fundamentals (namely a situation of public information) to a case in which speculators observe them with an even very small noise (namely a situation of private information), the situation changes dramatically and the area of uncertainty shrinks to a single point, that divides again the area of stability from the area of instability.

The explanation provided by Goldstein (2013) based on the logic of backward induction, is particularly clear. Due to the existence of a noise, economic agents do not observe the exact state of fundamentals, but just a signal of it. However, the signal that they

[8] See Jeanne (2000) for a survey on the literature on speculative attacks.

receive, also says something about the signal that other agents may receive. If one speculator observes a signal which is extremely low, she knows, given the size of the error that the signal may contain – which is assumed to be known - that other speculators will never receive a signal above a given level and therefore will not attack. This will apply to all speculators who receive even lower signals. So, in the end it will be possible to identify a boundary below which nobody will attack, because it is known that no strategic complementarity can be enjoyed in attacking. The same approach can be followed on the opposite side: if the signal is above a given level, then it can be inferred that all other speculators will receive a signal that suggests that attacking is the right thing to do. Morris and Shin (1998) show that those two boundaries coincide, so that all speculators attack for a level of the economic fundamentals below a given threshold level and they do not attack for a level which is above.

The models described above, however, did not allow to interpret the causes of the 1997 South-East Asian crisis.[9] Krugman (1998) and Corsetti, Pesenti and Roubini (1998), for example, underlined the role played by moral hazard in causing the over-indebtedness of the private sector. According to this interpretation, the presence of either implicit or explicit guarantees on both the private and the public debt would have encouraged economic agents to give credit without paying too much attention to the uses the funds would be devoted to, so as to produce an excess of loans, indebtedness and domestic absorption (mainly consumption).[10] Had this observation received more attention, the global financial crisis that will take place about ten years later might have been avoided, given that a similar mechanism, applied to the sub-prime mortgages and the development of credit derivatives, is recognized as being at its origins.

Some authors interpreted the South-East Asian crisis as resulting from self-fulfilling changes in the state of expectations, given that – as in the case of the 1993 speculative attacks against France - macroeconomic indicators like public finance and inflation rate were in order (Goldstein, 1998, Chang e Velasco, 1998, Radelet e Sachs, 1998). Krugman (1999a) and Irwin and Vines (1999), however, pointed their attention to the weakness

[9] See, among others, Corsetti, Pesenti and Roubini (1998) for an accurate description of the events characterizing it.

[10] One possible interpretation suggests that the IMF intervention in 1994 in support of Mexico might have created the expectation of a similar intervention, still by the IMF, in South-East Asia.

represented by the *fragility of the financial system*, something that, in their view, called for the introduction of a 'third generation' of currency crises models. By accepting, at least at first sight, the self-fulfilling nature of the crisis, and by declaring the 'defeat' of his position, based on the role played by the divergence in economic fundamentals, Krugman (1999a) introduced into the analysis, then, the financial system.[11] According to this interpretation, the crisis would have had its origins in the exogenous shocks hitting some countries characterized by bad financial indicators and propagating to regions characterized by a similar situation, thereby changing the state of expectations on the markets.

The capital outflow that followed such shocks led to the need to balance the current account through a devaluation of the exchange rate and/or through the adoption of deflationary policies. Both measures would have affected negatively the balance sheet of companies and banks whose debt was denominated in foreign currency, thereby further stimulating the expectations of a devaluation/depreciation: a worsening of the exchange rate increases the weight of foreign denominated debt and worsens the liabilities of the companies; in turn, the reduction of economic activity reduces the value of the assets of the balance sheet. If investments are self-financed and depend on internal wealth especially because of imperfections in the credit market, as in the hypothesis made by Bernanke and Gertler, the devaluation of the exchange rate, by reducing the profits and, as a result, the investments, may have a negative effect on the real economy.

The processes of *internal* liberalization, then, caused a worsening of the financial component of economic fundamentals, while the process of *international* liberalization generated a situation of intrinsic instability, subject to sudden changes in the state of expectations also in the absence of 'fundamental' reasons.

More recently, Bergman and Jellingsø (2010) use a third generation currency crisis model - more precisely the model spelled out in different articles by Aghion, Bacchetta and Banerjee (Aghion, Bacchetta, Banerjee, 2000, 2001, 2004), in order to show that the

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[11] In spite of his previous negative answers to the questions "*Are currency crises self-fulfilling?*" (Krugman, 1996), Krugman (1999a), he recognizes the self-fulfilling nature of the Asian crisis: "*The Asian crisis has resolved the argument between 'fundamentalists' and 'self-fulfilling' crises stories (I was wrong; Maury Obstfeld was right)*" (Krugman, 1999a, p. 1).

restrictive monetary policy that is implemented to defend the exchange rate peg in the short run proves inconsistent in the medium run, thereby increasing the likelihood of a future crisis. Also Nakatani (2017), still using the Aghion, Bacchetta and Banerjee's approach identifies an inconsistency of a different type by comparing the negative effects produced by a currency depreciation on foreign currency denominated debt and the positive effects on exports. [12]

3. INTERPRETING THE EMS CRISIS AND THE CASE OF ITALY

The literature that has been surveyed above allows only a partial interpretation of the crisis that had been hitting several EMS countries in 1992-93. In the case of Italy, for example, given its large current account deficit, it is difficult to claim that the crisis was driven by negative self-fulfilling expectations (as the 'second generation' of currency crises models would suggest), rather than by a divergent state of economic fundamentals.

It is not possible to use the 'third generation' of currency crises either, given that they are mostly based on the financial fragility caused by an excess of private, rather than public, debt (it is not by chance, after all, that the 'third generation' was created after the South-East Asian crisis, given the difficulty of existing models to account for it).

But the remaining candidate, the 'first generation' of currency crises models – and in particular the seminal paper in this literature, namely Krugman (1979), is not fully appropriate either given that it assumes a monetary divergence driven by an expansionary domestic credit creation, that was appropriate to represent the Latin American crises that occurred in the 1970s but that did not fit the case of Italy, for example. As a matter of fact, as we have seen in Section 1 above, in the case of Italy the monetary base had been increasing because of the only partially sterilized capital inflows attracted by the relatively high nominal interest rates on the Italian public debt, rather than by a deliberate domestic credit divergence.

[12] In the Keynesian open economy model an exchange rate depreciation increases net exports. Krugman (1999b) and Aghion, Bacchetta, Banerjee (2000) had also pointed out that this effect can be partially (or even totally) compensated by the mechanism described above, so that the net effect might well turn out to be negative.

As a matter of fact, already Sutherland and Ozkan (1994) observed that domestic monetary policies in EMS countries had not been characterized by a domestic credit divergence over the period 1987-92. The same conclusion was reached by Rose (1994), who argued, as a result, that the presence of an *inconsistent trinity* did not find any empirical evidence. This is the reason why, according to Obstfeld (1995), monetary convergence would be a necessary, but not sufficient condition for exchange rate stability. Eichengreen *et al.* (1993) concluded therefore (although referring especially to France) that the speculative attack had a self-fulfilling nature, induced by the divergence represented by a high unemployment that created the expectation of an appropriate policy response, namely an exchange rate adjustment. Such an expectation, then, would be self-validated.

The divergence in the state of economic fundamentals (referring especially to the current account deficit) was recognized by Begg and Wyplosz (1993), who identified an inflationary divergence in some countries, but they attributed its causes to a divergence in unit labor cost.

Capital inflows, however, may also have played a role in determining a divergent inflation rate, also in line with the Walters' critique that have been recalled above in Footnote 3. This is not to at all to deny the role of unit labor cost divergence, given that (in line with what argued by Walters, 1986) capital inflows produce expansionary effects that, by heating up the domestic demand, may well explain the higher wages required by workers, as an immediate reference to the Phillips curve would also suggest.

Another aspect that is not well captured by existing models, is the fact that the speculative attack against the Italian lira was not as abrupt as Krugman (1979) or Broner (2008) models would predict instead, but it gradually piled up over the time span of a few months, determining an interest rate convex non-linearity (as we have seen in Figure 4 above). Moreover, the devaluation of the Italian currency became more and more predictable, rather than unpredictable, as suggested instead by Broner (2008) and by the 'second generation' of currency crises models (Obstfeld, 1986, 1995, 1996). Finally, as we have already observed, the divergence in the state of economic fundamentals was not coming from the private sector, as suggested by the 'third generation' of currency crises models, but rather from the public sector, as the 'first generation' represented.

In what follows I will be setting up a model, then, that represents the points that I have discussed above, namely the specificity of the crisis affecting Italy in 1992-93.[13]

I do this by considering a standard central bank's loss minimization model that accompanies a Mundell-Fleming type speculative attack model together with Tamborini's hypothesis of heterogeneous market beliefs (Tamborini, 2015), which he applied to the analysis of the euro area crisis. As already mentioned above, differently from the 'first generation' speculative attacks literature, that implied a sudden speculative attack on the remaining available foreign reserves in the anticipation of their depletion, this model allows to account for the interest rate convex non-linearity represented in Figure 4 above and implying a gradual - but growing at an increasing rate - accumulation of speculative positions. Moreover, differently from 'second generation' models, the speculative attack is not unpredictable, and the dynamics that follows the occurrence of a stochastic shock is better modeled and explained.

The fact that similar theoretical approaches (I am referring in particular to Tamborini's hypothesis of agents characterized by heterogeneous beliefs) can be applied to the analysis and interpretation of both the euro area crisis and fixed exchange rate crises, like the one that affected the European Monetary System in 1992-93, is not new. As a matter of fact, even the opposite direction has been followed, because the synthesis of the currency crises models and literature has been applied by Della Posta (2016a and 2016b respectively) to the interpretation of the euro area crisis and to foreign debt crises. This is not to mean that such exercises are far from useful. In fact, quite the opposite can be concluded: the fact that already other papers show a parallel between the euro area crisis and the EMS crisis provides further evidence of the possibility of very fruitful insights that can be obtained by referring to both cases.

4. THE MODEL

The model that I am going to present below has three main ingredients.

[13] I also think that this conclusion could be generalized to other countries and other environments, as I may want to investigate in my future research.

The first one is the assumption of agents characterized by heterogeneous market beliefs. As we have seen in the survey of the literature on currency crises, Broner (2008) departed from Krugman's assumption of perfectly informed agents and introduced the assumption of a share of informed agents and a complementary share of uninformed ones. As a matter of fact, considering the 1994 Mexican crisis, he finds "*likely*" the presence of a share of fully informed economic agents, and, referring to the 1997 South East Asian crisis he finds "*reasonable* to suppose that some insiders had an informational advantage over the other investors". He also concludes that "overall there does seem to be *substantial indirect evidence*" (Broner, 2008, p. 594) which is consistent with the hypothesis of a share of informed and a complementary share of uninformed agents. The adjectives (that I have emphasized) used by Broner (2008) in what precedes, however, suggest that his hypothesis of two groups of market participants, one being informed and the other one being uninformed, although argued in plausible terms, is not supported by an uncontroversial evidence. I believe, then, that the validity of his even stronger assumption that a "subset of informed consumers knows the level of Central Bank reserves at which the peg will be abandoned" (Broner, 2008, p. 594) could also be questioned. As a matter of fact, if his assumption was correct, it would not be clear why George Soros in September 1992, just to refer to a well-known example, had some specific information allowing him to predict with certainty the timing of the imminent devaluation of the British pound and of the Italian lira, so as to earn about 2 billion of US dollars, while a couple of years later he lost an approximately equal amount of money in speculating against the US dollar, as some anecdotal evidence reports. How comes that he was not fully informed in the second case too? Moreover, even if we accepted the idea that a small share of market participants knew the 'true' state of economic fundamentals, in a free market economy it is difficult to imagine that segmentation can be so tight to allow them to keep the secrecy on the private information they own. So, even if, at least in principle, some private information of informed agents, as opposed to the public information of uninformed agents, might be possible, either it remains limited to an un-significant and close to zero market share or, if its diffusion increases, it will be such as to quickly transform private information into public.

I find it more realistic and more general, then, to depart completely from the original Krugman's hypothesis of perfectly informed economic agents and to extend to its extreme point the assumption made by Broner (2008) that only a share of economic agents is not

perfectly informed. In the model that I am going to present below, then, I follow Tamborini (2015) in assuming that no agent has an informational advantage over the others but rather that the beliefs of all market participants are distributed around their true mean.

As we will see, assuming heterogeneous market beliefs allows on one hand to take into account the role played by the state of economic fundamentals, as it is done in the 'first generation' of currency crises models, and on the other hand to explain the dynamics of the accumulation of destabilizing expectations, something that the self-fulfilling approach introduced with the 'second generation' modeling leaves unexplained, since it simply relies on the occurrence of a stochastic shock changing the state of expectations.

The second ingredient is represented by a first generation speculative attack model à la Mundell-Fleming/Krugman in which an IS-LM model is considered but in which monetary divergence - differently from Krugman (1979) (whose model could be applied to the specific case of Latin American countries in the 1970s) but in line, instead, with the Walters' critique (Walters, 1986) - arises because of the expansionary effects of the only partially sterilized net short term capital inflow, rather than because of a divergent central banks' creation of domestic credit.

Since the net unsterilized capital inflow increases the monetary base and through this channel it may induce a higher inflation rate that appreciates the real exchange rate and worsens the current account, there might be a critical level of the latter that will be considered as unsustainable and above which an exchange rate devaluation will be thought as inevitable. One of the variables that economic agents may consider in order to draw a conclusion and form their expectations is the overall stock of foreign reserves that the central bank could mobilize in case of need (especially because, as it has been well documented, short term capital may flow in easily, but only temporarily, and they could as easily flow out of the country – the well-known *capital flights*). This means that the lower threshold below which foreign reserves cannot go plays an important role in reassuring economic agents: the lower it is, the larger the overall availability of foreign reserves is in case of a sudden outflow, and, as a result, the larger the current account deficit that might be considered as sustainable. Such a critical level is assumed not to be known by economic agents, who are assumed instead to have heterogeneous beliefs about it.

The third ingredient of the model is a Barro-Gordon type central bank minimizing a loss function whose two objectives are characterized by a trade-off between them.

The central bank is assumed to minimize the following quadratic loss function, that I

indicate with L_t:

$$L_t = (Y^F - Y_t)^2 + \beta(R_t - R^*)^2 \quad (1)$$

The variables are as follows: Y^F is the full employment level objective for the central bank, Y_t is the current output level, R_t and R^* are respectively the current level of foreign reserves and the desired and targeted level that would imply a smooth viability of the fixed exchange rate system. Parameter β is, instead, the relative weight that is assigned to foreign reserves (and money supply) variability with respect to output variability around its full employment target.

Not surprisingly, there is a trade-off between the two components.

The first component refers to the loss resulting from the output variability with respect to the full employment target (Y^{Full}).

The second component refers instead to the need to avoid an excessive divergence of the stock of unsterilized foreign reserves with respect to the level which is compatible with an orderly functioning of the fixed exchange rate system. As a matter of fact, when capital inflows increase foreign reserves and induce a higher money supply (because the central bank does not sterilize fully its expansionary effects) the inflation rate increases (given the positive correlation between the two) [14], thereby appreciating the real exchange rate, reducing the competitiveness of the country and worsening the current account deficit. The latter (with the corresponding stock of foreign capital) threatens the stability of the fixed exchange rate if it reaches such a high level that foreign creditors start fearing about its sustainability, and a *capital flight* takes place.

[14] After all, it is precisely on the validity of the correlation between domestic credit creation and inflation rate that the celebrated Barro and Gordon (1983) model is built, given that the assumption that the central bank can choose the optimal level of the inflation rate, implies that there is an instrument – domestic credit creation - allowing such a direct control. The correlation between domestic credit creation and inflation rate weakened considerably after the 2007-2008 global financial crisis (as it is further confirmed, for example, by the fact that the ECB has been unsuccessfully struggling for the last few years in order to increase the inflation rate to a level "below but close to 2%"), but it was still valid over the years 1992-93 that I am considering in this paper. It needs to be observed that the breaking up of such correlation may have quite strong implications for the validity of the conclusions reached by the Barro and Gordon (1983) model, upon which the whole of credibility theory is based. I am planning to investigate those implications in my future research.

Parameter β, then, could even be interpreted as the weight assigned to the objective of stabilizing the inflation rate and of keeping the exchange rate fixed. From this point of view, then, the loss function is not different, in the substance, from the one which is usually assumed in credibility theory models (Barro and Gordon, 1983), in which the central bank faces an explicit trade-off between inflation variability and output variability.

In this model the loss minimization is subject to both the IS constraint:

$$Y_t = \bar{Y} - \alpha i_t^h, \tag{2}$$

and the LM constraint:

$$M_t = R_t + DC_t = kY_t - hi_t^h \tag{3}$$

In Equation (2), $\bar{Y}$ is the 'structural'[15] level of output at which the economy would be in equilibrium (but not necessarily at a full employment level). The variable i_t^h is the home interest rate, and α is the interest rate elasticity of domestic investments.[16] In Equation (3) parameters *k* and *h* indicate, respectively, the output elasticity and the interest rate elasticity of money demand, in turn reflecting, respectively, the well-known Keynesian transactional and speculative reasons for money demand. R_t, as we know, is the stock of foreign reserves, which appears in the assets side of the central bank's balance sheet, while DC_t is the domestic credit made available by the central bank to the domestic economy through open market operations, still appearing on the left/assets side of the central bank's balance sheet. We can assume that the central bank is well aware of the 'inconsistent trinity' problem (resulting also from the experience of the 1970s in Latin America) and for this reason it keeps domestic

[15] See Blanchard (2017) for a definition of 'structural' unemployment (namely the one resulting from the 'structure' of the economy, including the degree of market competitiveness or of labor market rigidities), that here I am extending to output.

[16] In order to avoid unnecessary complications in the model, in the IS equation I have not included the external channel determining a reduction of the domestic demand resulting from an appreciation of the real exchange rate. As a matter of fact, the presence of such an external channel can be assumed to weaken the expansionary effects of an interest rate reduction resulting from a higher monetary base, but not to revert it. Giavazzi and Pagano (1986??) for example, also assume that the contractionary effect of a surprise inflation always exceeds the contractionary effect resulting from a reduction of external competitiveness.

credit constant, so that $DC_t = \overline{DC}$.

By rearranging the LM equation, we have that:

(3') $$i_t^h = \frac{k}{h} Y_t - \frac{1}{h}(R_t + \overline{DC})$$

By taking the value of Y_t from the IS and plugging it into the rearranged LM equation above, it follows that:

(4) $$i_t^h = \frac{k}{h+\alpha k} \overline{Y} - \frac{1}{h+\alpha k}(R_t + \overline{DC}).$$

As a result, the value of the unsterilized net inflow of foreign reserves that minimizes the loss function is obtained when:

(5) $$\frac{dL_t}{dR_t} = \frac{d(R_t - R^*)^2}{dR_t} + \frac{d\beta(Y^F - Y_t)^2}{\partial Y_t} \frac{\partial Y_t}{\partial i_t^h} \frac{\partial i_t^h}{dR_t} = 0$$

That gives:

$$R_t = R^* + \frac{\alpha}{\beta}(Y^F - Y_t)$$

In turn, considering the IS, this corresponds to:

(6) $$R_t = R^* + \frac{\alpha}{\beta}(Y^F - \bar{Y}) + \frac{\alpha^2}{\beta} i_t^h.$$

Equation (6) represents the reaction function of the monetary authority to the value taken by the interest rate, as determined by the private sector (resulting from the aggregation of economic agents). Given the positive sign of the relationship between R_t and i_t^h, what this suggests is that the higher the interest rate is (thereby depressing output), the higher is the incentive for the central bank to increase the unsterilized inflow of foreign reserves, in order to increase the money supply and induce an interest rate reduction. In turn, unless the inflation rate also drops, the real interest rate will also go down. As in the Walters' critique, the lower real interest rate will heat the economy up and will determine and increase of the inflation rate

(for example because of the effects of a lower unemployment on nominal wages as in the standard Phillips curve case), that on one hand will further heat the economy up, but on the other hand will crowd the external channel out.

Let us turn, now, to the private sector. The domestic interest rate that the private sector charges on domestic bonds is given by a standard interest rate arbitrage:

$$i_t^h = i^f + FD \tag{7}$$

In Equation (7) above, i^f is the interest rate of the foreign partner in the fixed exchange rate regime (that we can consider as fixed and exogenously given) and *FD* is the expected forward discount on the domestic currency, namely the risk premium resulting from the future expected devaluation of the domestic currency.

Following Tamborini's approach (Tamborini, 2015), whose model applies to public debt rather than currency crises, as it is the case in this paper instead, the value of *FD* is assumed to depend on the ratio between the probability of devaluation (*p*) and its complement:

$$FD = \frac{p}{1-p}. \tag{8}$$

In turn, the probability of devaluation can be assumed to depend on the stock of capital inflows generating a net unsterilized increase of foreign reserves. The reason is that the higher is the amount of unsterilized foreign reserves, the higher is the inflationary pressure on the domestic economy, given the assumed relationship between monetary base and inflation rate, causing an appreciation of the real exchange rate and a further worsening of the current account deficit.

We assume that the private sector (being composed by agents characterized by heterogeneous market beliefs) does not know with certainty the maximum value of the inflow of foreign capital that can be allowed without hitting the threshold represented by the availability of foreign reserves. Let us assume, then, that agents expect such a limit, $\bar{R}$, to be included between a minimum and a maximum possible value, respectively $\bar{R}_{min}$, and $\bar{R}_{max}$. In particular, as a simplifying assumption, let us consider the case of a uniform distribution of beliefs about the maximum possible level of domestic credit that can be run in order to keep

the exchange rate parity (namely $\bar{R} \sim U(\bar{R}_{min}, \bar{R}_{max})$), so that: [17] $f(\bar{R}) = \frac{1}{\bar{R}_{max} - \bar{R}_{min}}$.

The assumption of the uniform distribution of $\bar{R}$ leads also to conclude that its expected value (or 'market belief', as Tamborini, 2015, defines it), is nothing but the average between the maximum and the minimum level that the upper limit can take, namely: $\bar{R}_M = \frac{\bar{R}_{max} + \bar{R}_{min}}{2}$, where $\bar{R}_M$ is the foreign reserves threshold which is expected by the market. It can also be assumed, as a result of the hypothesis of rational beliefs, that $\bar{R}_M = \bar{R}$, so that the market works as a 'beliefs aggregator'. This equality will be used below when discussing the case in which the market varies the boundaries of the uniform distribution of $\bar{R}$.

Having assumed as a simplifying assumption a uniform distribution function means that the cumulative distribution function of agent's beliefs about the minimum value that foreign exchange reserves can take (corresponding to the devaluation probability, *p*) is:

(9) $$p = F(R_t) = \int_{\bar{R}_{min}}^{R_t} f(\bar{R}) d\bar{R} = \frac{R_t - \bar{R}_{min}}{\bar{R}_{max} - \bar{R}_{min}}$$

It follows, then, that:

$$FD = \frac{R_t - \bar{R}_{min}}{\bar{R}_{max} - R_t},$$

from which we have:

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[17] Tamborini (2015) restricts his attention to two possible distributions, the normal and the uniform, both of them being capable to produce a convex private sector's reaction function, which is the only one to provide a realistic representation of the interest rate behavior in speculative attacks (a concave interest rate function would be implausible for obvious reasons). He focuses his attention to the normal distribution given that "normality is a (sensible) case, where opinions are relatively concentrated around the market belief (…) with symmetric tails of optimists and pessimists" (p. 1163). I take instead the case of a uniform distribution that, in spite of its lower degree of realism, allows providing an analytical and very intuitive representation of the interest rate behavior resulting from the private sector's reaction function. No substantial difference, however, derives from one assumption or the others. Obstfeld (1986) also considers a uniform distribution for the shock hitting a fixed exchange rate system, not necessarily for its degree of realism, but rather for its simplicity.

(10) $$i_t^h = i^f + \frac{R_t - \bar{R}_{min}}{\bar{R}_{max} - R_t}.$$

This is how the private sector reacts to the unsterilized net inflow of foreign reserves, so that whenever R_t increases, the probability that it will reach the upper limit increases very little when R_t is close to $\bar{R}_{min}$ and far away from $\bar{R}_{max}$, while it increases exponentially, and the devaluation risk increases with it in the same way, when R_t is far away from $\bar{R}_{min}$ and it approaches $\bar{R}_{max}$.

To summarize, the reaction functions of the central bank and of the private sector are respectively Equation (6) and Equation (10). They can be represented together in Figure 5 below.

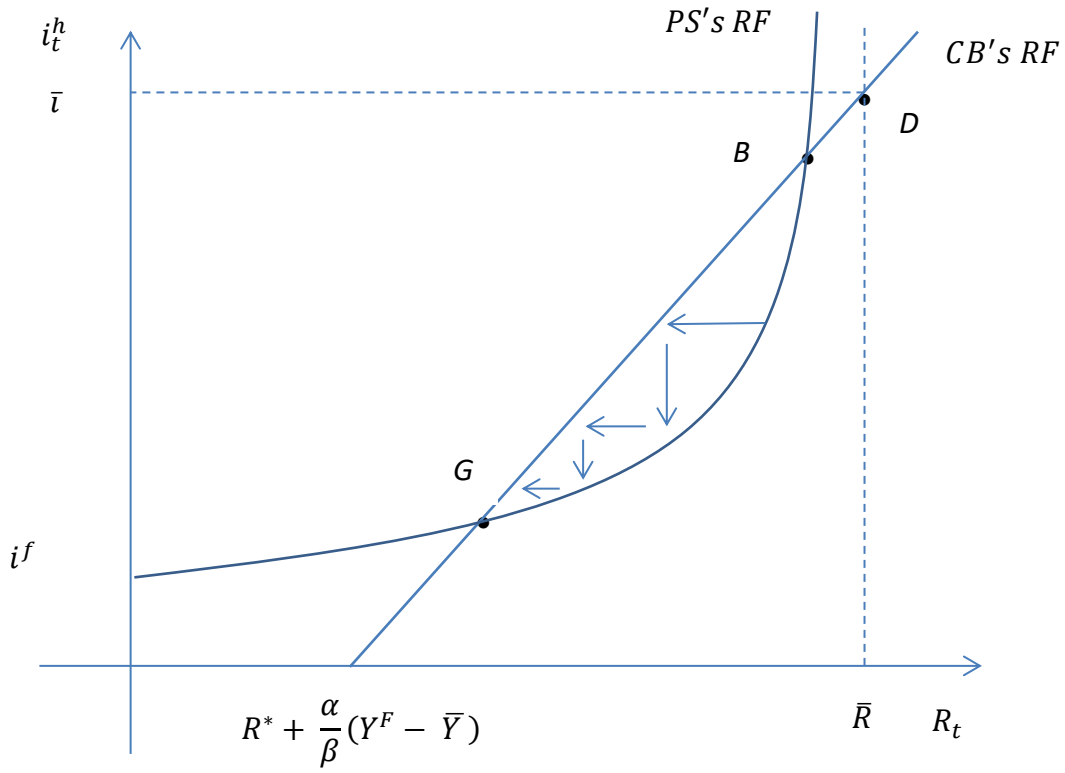

Figure 5: Central bank's and private sector's reaction functions ($CB's\ RF$ and $PS's\ RF$, respectively) and the multiplicity of equilibria: the good (G) and the bad (B) one.

As in the case of public debt default analyzed by Tamborini (2015), Figure 5 above identifies some different equilibrium points (up to two) and a default point. The two equilibria are the good one (low i_t^h and low R_t, identified with *G*) and the bad one (high i_t^h and high R_t, identified with *B*). The devaluation point (*D*) is obtained where the CB's reaction function reaches the maximum available level of the foreign exchange reserves ($\bar{R}$) and the corresponding maximum interest rate level ($\bar{\imath}$). When R reaches $\bar{R}$, the trade deficit has increased so much that it is not believed to be sustainable anymore, so that no exchange rate defense will be possible anymore the exchange rate will have to be devalued.

It is easy to see also from the arrows in Figure 5 that any point whose coordinates are lower than those of point *B* in either of the two variables defining it, will be attracted by the "good" equilibrium, *G*. For any value of R_t and/or i_t^h larger than the one(s) defining point *B*, instead, the system is pushed to the exchange rate devaluation that takes place in point *D*.

What precedes allows to account for the convex non-linearity that characterized the behavior of the interest rate of some of the countries whose currencies were under attack in the EMS in 1992-93 and that has been shown in the Introduction: the continuous inflow of foreign reserves at some point started determining the expectation in a larger and larger share of economic agents, that the sustainability threshold was going to be hit soon, and this induced a higher risk premium and higher interest rates.

5. ANALYSIS OF THE PRIVATE SECTOR'S REACTION FUNCTION

Let us analyze now more in detail the reaction function of the private sector. As Equation (10) clearly shows, the interest rate equation flattens when either $\bar{R}_{max}$ or $\bar{R}_{min}$ increase. This implies that $\bar{R}_M$, the expected value (market belief) of $\bar{R}$, defined above, increases too. Such an expectation allows to increase the unsterilized inflow of foreign reserves and shifts both *B* and *D* respectively to *B'* and *D*', as it is clearly shown in Figure 6. Moreover, if the domestic economy is in the bad equilibrium *B*, the possibility to stand a further capital inflow resulting from an increased degree of confidence in the stability of the exchange rate system (for example because of the availability of additional resources to guarantee foreign creditors), leads to the good equilibrium *G*, as also shown in Figure 6 (but a different one, characterized by a lower i_t^h and a lower R_t might also be possible).

Needless to say, the opposite is also true. As described in the Introductions, this is what happened during the life of the EMS, when the Basel-Nyborg agreement was reneged, given the fear that such an intervention might have caused an increase of the German inflation rate. The reduction in the availability of foreign reserves reduced the availability of resources to guarantee the sustainability of the current account deficit, thereby encouraging speculation.

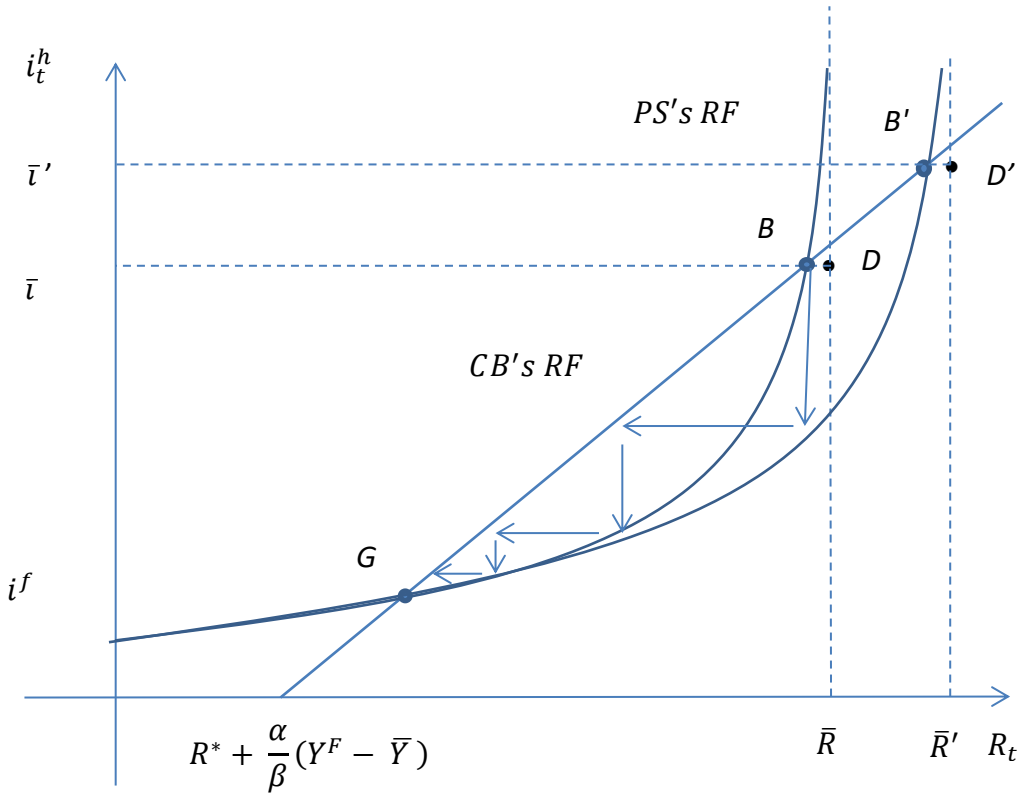

Figure 6: The effect of a larger expected $\bar{R}$

Let us consider now what is the effect of a higher foreign interest rate. In Figure 7, point *B* identifies, as we know already, the "bad" equilibrium below which any position out of equilibrium is attracted towards the good equilibrium *G*.

When i^f increases to $i^{f\prime} > i^f$, this has two effects. The first is clearly to shift the private sector's reaction function upwards. The second - as long as a high i^f implies a lower foreign credit creation $DC^{f\prime} < DC^f$ - is a leftward shift of the central bank's reaction function. If the domestic economy is in the good equilibrium (*G*), there are no significant changes and the system dynamics leads to the new good equilibrium *G'*. If, instead, the

domestic economy is in the bad equilibrium, *B*, the consequences will be very negative, leading to a devaluation, given that the interest rate that would be necessary to peg the exchange rate exceeds the highest feasible one.

This is precisely what happened in the EMS after the interest rate increase undertaken by the Bundesbank due to the need to avoid the risk of inflation resulting from the adoption of a 1-to-1 conversion rule between the East and the West German Mark. Several authors identify this event as being at the origin of the speculative attacks of 1992.

The same graphical representation proposed in Figure 7, however, can be used to depict the events occurred in the Spring of 1992, that changed the state of expectations about the perspectives of the monetary union, and therefore about the future of the EMS. As I have recalled above, with the referendum that took place in June 1992, the Danish people rejected their adhesion to EMU and this event acted as a catalyst for a change in the state of expectations. The effects of such a change can be represented by a shock hitting the interest rate that adds a further exchange rate devaluation risk premium on the interest rate parity equation. Equation (10), then, can be rewritten as:

(10') $$i_t^h = i^f + \frac{R_t - \bar{R}_{min}}{\bar{R}_{max} - R_t} + \varepsilon_t,$$

where ε_t is a stochastic shock hitting the interest rate parity equation, and implying that the domestic interest rate has to be further increased if the fixed exchange rate is to be maintained.

An exchange rate credibility shock affecting the risk premium, then, no matter what its origin is, can be described exactly as it is done for the case of an increase of the foreign interest rate described above, since they both imply a higher domestic interest rate which is necessary to guarantee the interest rate parity.

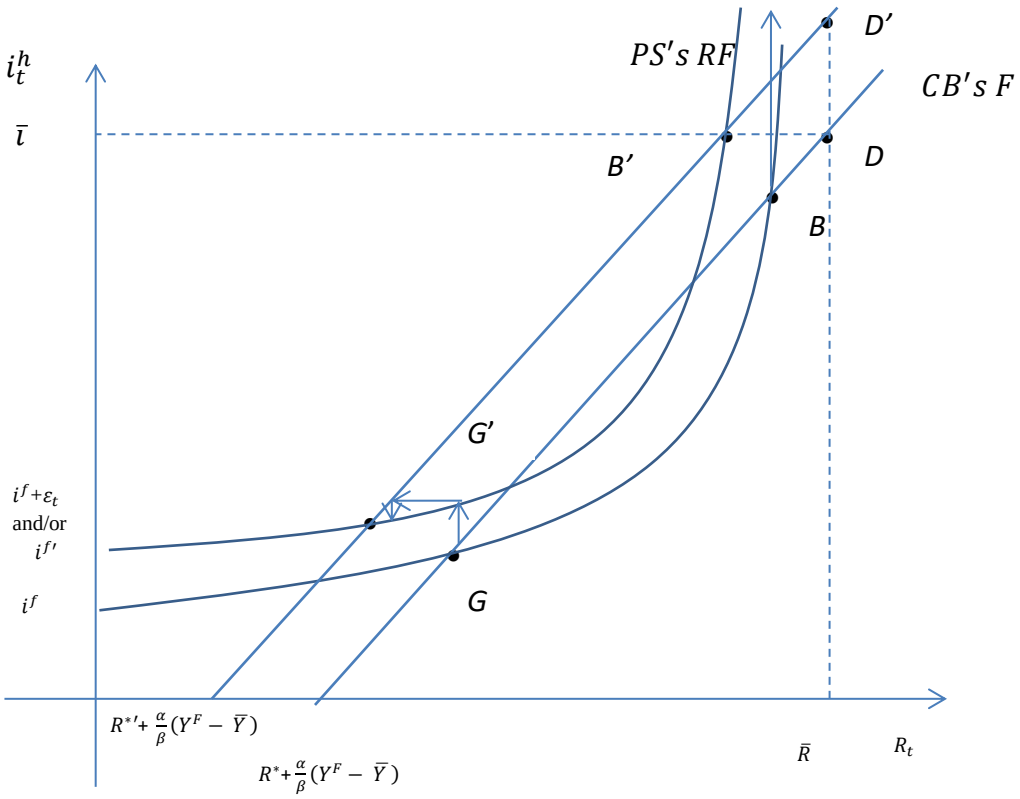

Figure 7: The effect of a foreign interest rate shock or of a risk premium shock on the good and bad equilibriums

A third case can also be considered, relative to the effects of a larger uncertainty on the availability of foreign reserves, so that the private sector's reaction function gets smoother and flatter, being capable, therefore, to move the domestic economy from the bad equilibrium *B* to the good equilibrium, *G'*, as shown in Figure 6. The effect of the Basel-Nyborg agreement not being honored can also be interpreted as reducing the degree of uncertainty about the availability of foreign reserves, therefore reducing the sustainable level of the current account deficit, and in turn reducing the maximum level of unsterilized capital inflows, R_t. Such a higher degree of uncertainty of the availability of foreign reserves induces a flattening of the private sector's reaction function for low levels of R_t, and further steepening of it, thereby increasing the interest rate convex non-linearity, for high levels.

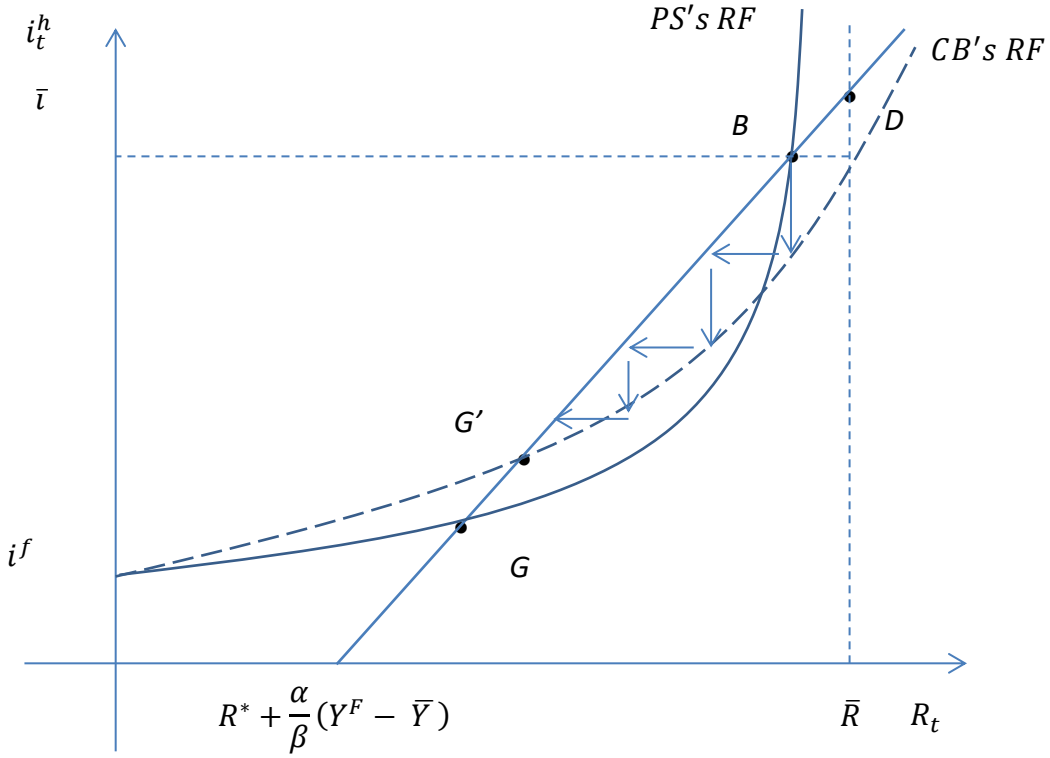

Figure 8: Higher uncertainty on the feasibility of capital inflows (implying a trade deficit and the accumulation of external debt)

6. ANALYSIS OF THE CENTRAL BANK'S REACTION FUNCTION

As Equation (6) shows, the lower the weight that the domestic country assigns to reserves variation, β, the higher the unsterilized inflow of foreign reserves that the central bank is willing to accept and, as a result, the lower the level of the domestic interest rate at which a devaluation will take place. This conclusion derives from the fact that the private sector reacts to the higher inflow of foreign reserves (that increases the risk of reaching the upper limit at which the real appreciation of the exchange rate induces a trade deficit which increases external debt to an unsustainable level), with a higher interest rate, thereby reducing the stability region (see Figure 9). A change of central bank's preferences, moving from β to $\beta' < \beta$, then, would destabilize an economy which is in a bad equilibrium and will lead to a devaluation. Of course, the opposite would also apply: making a central bank more adverse to

the destabilizing inflow of foreign reserves would stabilize the economy and it would lead from the bad equilibrium *B'* to the good one, *G*.

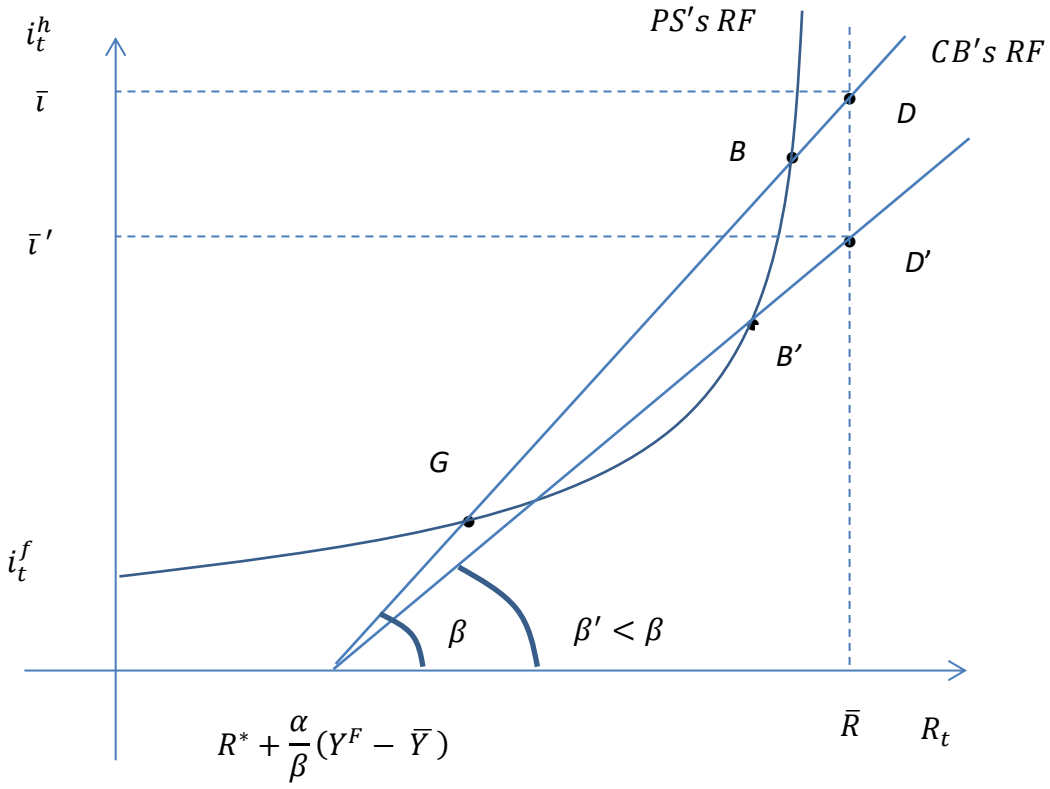

Figure 9: A lower β, namely a lower weight assigned by the central bank to the inflationary effects of the unsterilized inflow of foreign reserves, implies a lower critical value for the interest rate, $\bar{\iota}'$ at which the currency is attacked (or devalued)?

The model can be extended to incorporate also the effects of a negative stochastic shock on the real economy, something that characterized the existence of the EMS and preceded its 1992 -93 crisis. Such a shock affected, among others, France, a country that would be otherwise characterized by a good state of economic fundamentals (like inflation rate, public deficit and public debt). Let us introduce a stochastic shock ε_t in the equation below:

$$Y_t = \bar{Y} - \alpha i_t^h - \varepsilon_t,$$

where ε_t is a shock that hits negatively the domestic output.

By considering the stochastic equation above, the central bank's reaction function in Figure 10 shifts to the right by the size of ε_t, so that the critical level for the interest rate above which the stability of the fixed exchange rate system is not granted any more, becomes lower. Moreover, the "bad" equilibrium gets lower and the area of instability leading to devaluation enlarges. The analysis of this point in similar to the one made by Tamborini (2015) for the case of public debt crisis. Similarly, two different hypotheses can be made as to the size of the shock, namely that it can be either small or large.

In the case of a small shock, if the equilibrium is in *G*, the optimal size of the unsterilized inflow of foreign reserves chosen by the central bank in order to minimize its loss function will increase slightly, so as to allow the equilibrium to move to *G'*. However, if the system was in *B*, even a small shock would be sufficient to lead to a self-fulfilling speculative attack and to a devaluation, by pushing towards *D'* and to an infinitely high risk premium (see Figure 10).

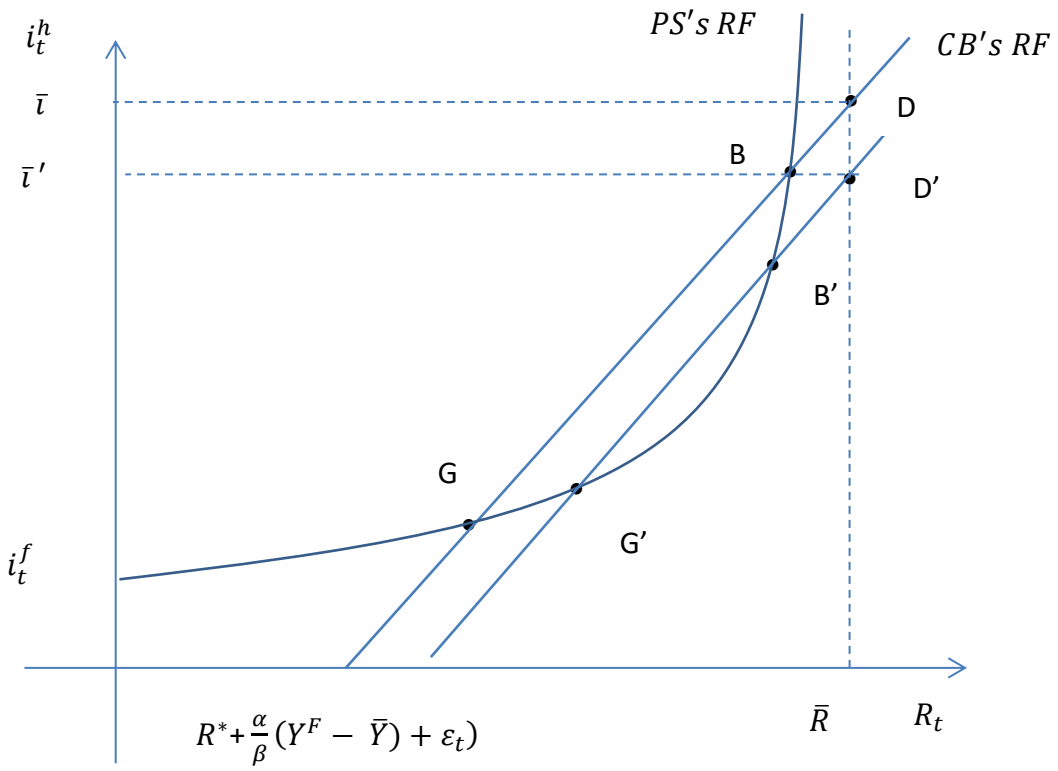

Figure 10: A negative 'small' output shock shifting the central bank's reaction function to the right and determining a self-fulfilling speculative attack if the initial equilibrium is in *B*.

In the case of a large shock, instead, contrary to the case of a small one, even a good equilibrium can be dislodged so as to go to the devaluation point, *D*. Of course, this will only be the case if there is no other way to guarantee the stability of the trade deficit of the country, namely if no extra foreign reserves are available. In the case in which $\bar{R}$ can be increased (let us think of the Basel-Nyborg agreement, that during the life of the EMS seemed to imply an unlimited support of the Bundesbank to the EMS central banks under pressure), then the private sector's reaction function also changes shape by prolonging its trajectory rightwards (See Figure 11).

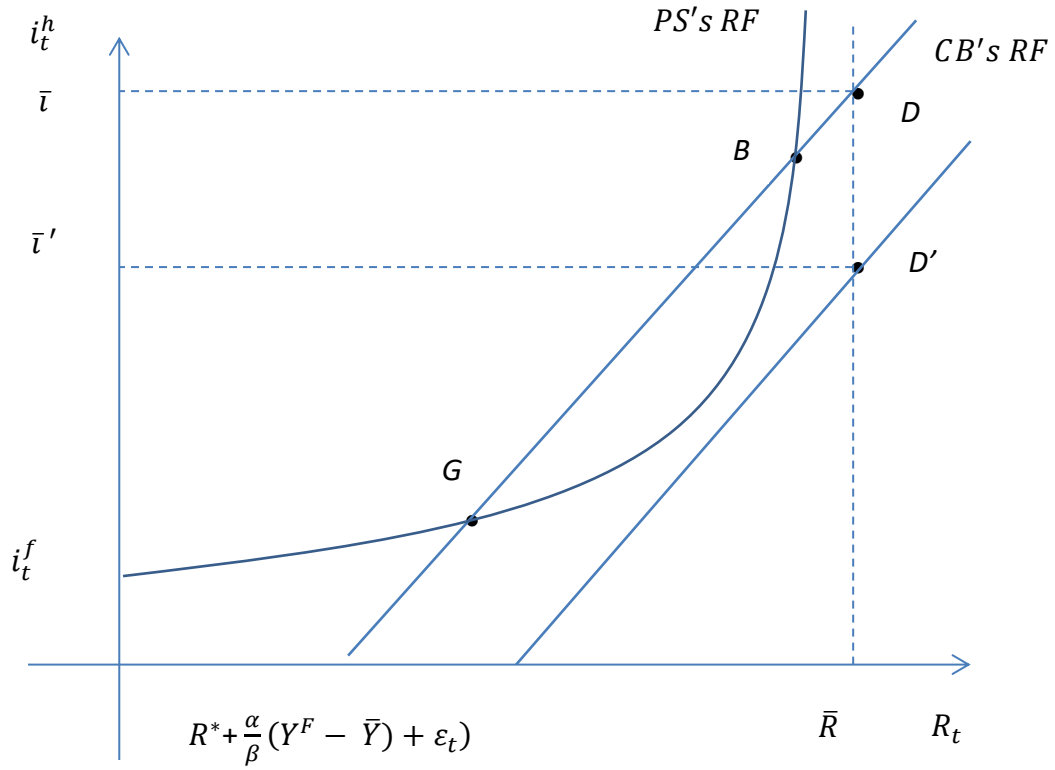

Figure 11: A negative 'large' output shock shifting the central bank's reaction function to the right and determining a self-fulfilling speculative attack.

7. CONCLUDING REMARKS

In this paper I have presented a currency crisis model that follows closely the approach adopted by Tamborini (2015) in analyzing the public debt euro area crisis, being based on the assumption of an economy composed by agents endowed with heterogeneous market beliefs.

Similarities between the two types of speculative attacks are quite significant, and it is not surprising that the tools and techniques used in the analysis of one could be applied to the analysis of the others. As a matter of fact, the essential elements of the speculative process remain the same, while the only thing that changes is the object of the speculative activity, public debt bonds in one case, currencies in the other one.

The model has produced the multiplicity of equilibria characterizing currency crises. However, it also showed how self-fulfilling speculative attacks could take place as a result of any of the possible changes in the model parameters.

Such effects are capable to explain the 1992-93 EMS crisis. In particular, the model explains how the unsterilized inflow of foreign reserves, determining a divergent inflation rate, the increase of German interest rates, the German refusal to honor the commitment taken with the Basel-Nyborg agreement, and the negative expectational and output shocks hitting the European economy in 1992, they all contributed to the realization of the EMS crisis.

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