LUISS Guido Carli

School of European Political Economy

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REDENOMINATION RISK AND BANK RUNS IN A MONETARY UNION WITH AND WITHOUT DEPOSIT INSURANCE SCHEMES[§]

Paolo Canofari*, Alessandra Marcelletti, Marcello Messori*****

Abstract

This paper develops a basic framework characterized by a monetary union in which a shock to the policy interest rate, to be intended as the determinant of a recessionary stance in the monetary policy, can imply that a member state finds it worthwhile to leave this union and/or that the corresponding banks declare bankruptcy. Our aim is to analyze the various possible reactions that bank depositors may have when this shock is transmitted to the interest rates on their bank deposits. We compare these reactions in two different policy frameworks characterized either by the presence or by the absence of a Centralized Deposit Insurance Scheme (CDIS). Our model shows that the introduction of CDIS is per se not sufficient for zeroing the probability of bank runs.

Keywords: Bank run, Monetary Union, Euro breakup, Redenomination risk.
JEL: F30, F31, F41, G01

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* Assistant professor, LUISS; Researcher at the Luiss School of European Political Economy (SEP).
** Researcher at SEP.
*** Professor, LUISS; SEP's Director

1. Introduction

The Banking Union has been the most ambitious initiative and a partial success in the recent evolution of European economic governance. The need for this initiative was emphasized in various interventions by the leaders of the International Monetary Fund, the European Central Bank (ECB), and other European institutions; the related process was launched in June 2012 with the first Euro-Summit meeting.[1] The Banking Union process led to the approval of the Single Supervisory Mechanism (SSM) by December 2012, as well as to the approval of the Single Resolution Mechanism (SRM) and the Single Resolution Fund (SRF) by mid-2014.

The SSM, which is compulsory for the member states of the euro area and can be adopted by other countries that belong to the European Union on a voluntary basis, centralizes the responsibility of bank supervision in the hands of the ECB (the first pillar of the Banking Union). The ECB directly supervises the bigger European banks (the so-called 'significant banks'), whereas it usually delegates the supervision of the smaller European banks (the so-called 'less significant banks') to the previous national supervisors. The SSM became operative at the beginning of November 2014. The SRM, which centralizes the processes of restructuring or of an orderly bankruptcy for the European banks with a public utility impact that are failing or are likely to fail (the second pillar of the Banking Union), is based on private sector involvement by means of the 'bail-in'; alternative forms of intervention on banks likely to fail require – at least – 'burden sharing'.[2] The SRM became operative in two steps (at the beginning of, respectively, 2015 and 2016) and it is still incomplete since the SRF is under construction and a

[1] The Euro-Summit is a subset of the European Council, since the former just includes the Prime Ministers or the Presidents of countries that belong to the euro area. The introduction of the Euro-Summit as a new European institution is related to the approval of an international treaty, well known under the label of Fiscal Compact (March 2012).

[2] The main difference between the bail-in and the burden sharing is that the former implies the possible involvement of all the bondholders (with the exception of the holders of covered bonds) and of the holders of deposits over 100,000.00 euro (non-guaranteed deposits), whereas the latter also excludes senior bonds (i.e. uncovered 'plain vanilla' bonds) as well as any type of deposits.

centralized operative 'backstop' is lacking.[3]

The aim of this paper is not to offer a general assessment of the two pillars of the Banking Union (see, for instance, Beck 2012, Hellwig 2014, Barucci and Messori 2014, Schoenmaker and Veron 2016, Micossi 2017). For our purposes, it is sufficient to recall that the original design of this process, as set by the European Commission in the fall of 2012, was based on three pillars. The third pillar, centered on the construction of the European Deposit Insurance Scheme (henceforth EDIS), has never been implemented. Four years ago, the European Commission (2015) launched a regulatory draft for the gradual construction of an EDIS aimed at covering the total amount of European deposits not greater than 100,000.00 euro from 2024 onwards; however, the 'core' euro-area member states blocked the possible regulation. Then, in the fall of 2017, the European Commission tried again to overcome the vetoes on this topic by suggesting a temporary compromise: introduce a European line of loans in favor of the national deposit insurance schemes under stress and build a centralized insurance scheme only after the approval of a shared agreement on risk reduction in the European banking sector. This weak and temporary form of EDIS, which was rephrased as a definitive solution in some academic papers,[4] was also not successful. Apparently, in their meetings in December 2018, the European Council revived this compromise by planning to restart the discussion on EDIS in the near future. However, no substantial commitment has been taken yet.

From a policy point of view, it is crucial to specify the causes of this stalemate. EDIS would inevitably imply some (strong or weak) form of risk sharing among the countries and the national banking sectors of the euro area. Hence, according to the 'core' countries, the idiosyncratic risks which characterize

[3] In the meetings of December 2018, the European Council and the Eurogroup launched the construction of a backstop to be built and managed by the European Stability Mechanism (ESM). This new tool, which will become operative by 2024, does not meet the design of the original backstop.

[4] See Bénassy-Quéré *et al.*, 2018; and for a criticism: Messori and Micossi, 2018.

various banks of the most fragile euro-area countries would have to be reduced before the actual start of EDIS' construction. The most fragile countries had criticized this binding sequence between risk reduction and risk sharing on several occasions. However, all the finance ministers of the euro area have formally approved this sequence (see also IMF 2016).

The recent literature on the European banking sector (ECB 2018) stresses that there are at least three idiosyncratic risks affecting banks of the most fragile countries as well as of some 'core' countries of the euro area: an excessive incidence of non-performing loans (NPLs) and non-performing exposures (NPEs) towards the 'real' economy on banks' total assets, the over-branching that increases the trading costs, and the excessive weight of the domestic sovereign bonds held in banks' balance sheets. Various authors (for example, Bénassy-Quéré *et al.* 2018 and 2019) maintain that the most significant of these three risks is the banks' excessively large exposure towards domestic sovereign bonds. Hence, the crucial question becomes: is it appropriate for a national banking sector of the euro area to implement a substantial reduction in this large exposure to overcome the vetoes on the construction of EDIS? Policy designs offer positive answers (see Veron 2017). With this paper we would like to contribute to this discussion at a theoretical level by assessing the possible stabilizing role played by EDIS in a stylized model of a monetary union.

Obviously, our paper is not the first to address this kind of problem. There is a well-known strand of literature that analyzes the possible (de)stabilizing impact that centralized and public guarantee schemes have on bank deposits. In their seminal paper, Diamond and Dybvig (1983) showed that the key element in the prevention of banking crises is the credibility of an insurance program able to strengthen depositors' trust in the guarantees covering (up to a certain amount) their deposits. More recently, Kiriazidis (2017) argued that an insurance system is a crucial element of banking regulation, since it can reduce liquidity risks and thus improve the management of the banking system. Similarly, Leonello (2017) stated that public insurance can be an effective tool for improving financial stability without weakening the

constraints on sovereign solvency. On the other hand, Calomiris and Jaremski (2016) stressed that insurance on bank liabilities can create drawbacks in the depositors' effort to acquire an adequate amount of information before allocating their financial wealth and savings. The two authors assessed the U.S. experience of explicit deposit insurance schemes and concluded that the implementation of these schemes can create a severe problem of moral hazard, and thus increase systemic risks. Other contributions tried to combine the two sides of the debate by focusing on possible tradeoffs. For instance, Allen and Gale (2017) recognized that a government guarantee can be an efficient instrument for the prevention of panic-based crises; however, they also acknowledged that this guarantee may incentivize financial institutions to take excessive risks.

Our reading of this theoretical strand of literature is conditioned by the recent crises (2007-2009 and 2011-2013), which undermined trust in the accountability of banks and led to new forms of bank runs (see Blanchard 2009). Our belief is that confidence in the financial market can be restored only by providing a safety net for bank depositors. On this basis, our paper focuses on a more specific theoretical problem which was not addressed by the previous contributions. Let us refer to a monetary union where member states can 'leave' and banks can go bankrupt, thus creating redenomination risks and counterparty risks that are greater than 0 for wealth owners. In this framework the question is then: is a centralized deposit insurance scheme (CDIS) the right tool for keeping these risks under control?

To answer this question, we combine three different types of models: those utilized by the literature on the crises of the fixed exchange rate regimes (e.g., Krugman 1979; Obstfeld 1986,1988,1997; Jeanne 1997; De Grauwe and Ji, 2013); those elaborated by Canofari et al. (2015), and Canofari and Messori (2017); and those developed to analyze the banking and currency crises (Miller, 2003). The specific set of problems to be addressed largely overlaps those modelled by Miller's paper. However, our analytical framework mainly borrows from the second type of models. This implies that there are substantial differences between Miller's framework and ours.

Miller's framework refers to a fixed exchange rate regime. In this regime the national central bank of the country where various banks have a high risk of bankruptcy can in principle adopt an autonomous monetary policy that provides for the abandonment of the fixed exchange rate and permits the government to rescue the banks in trouble. Miller (2003) shows that this strategy is always available and dominates the alternative options, so that a bank run by depositors would become an irrational choice *ex post*. In our model, instead, the reference is to a monetary union that cannot be reduced to a fixed exchange regime. The former provides for neither easy exits nor national autonomous monetary policies. Hence, a bank run can be rational even *ex post*. Moreover, the difficulties of the exit suggest that our stylized model of the monetary union must formalize the cost of leaving the monetary union as uncertain, at least while there is no actual exit of one of the countries, which would open a Pandora's box. We illustrate this by following the path indicated by Hefeker and Neugart (2015) and by Eijffinger *et al.* (2018).

The rest of the paper is organized as follows: Sections 2 and 3 introduce the theoretical set-up and the related model; Section 4 determines the conditions under which a given member state finds it advantageous to leave the monetary union in the presence of a shock to the interest rate policy; Section 5 describes the reactions that depositors of this same member state have, given this type of shock and the related probability of an exit. We show that depositors' reactions can depend on the existence or not of a centralized deposit insurance scheme (CDIS) in the monetary union. Section 6 concludes the paper.

2. The analytical set-up

EDIS, defined as a centralized mechanism which offers full insurance to small depositors of all the euro-area banks going bankrupt,[5] is the key missing leg of the European Banking Union. To analyze the

[5] In the following of our paper, it is meaningless to specify the maximum institutional threshold (as stated above, 100,000.00

possible impact of EDIS in determining the probability that depositors of the euro-area member states run on banks, we propose a stylized model of a monetary union composed of n member states (with $n \geq 2$). The analytical structure of this model partially reproduces the one first utilized by Canofari *et al*. (2015). Our general hypothesis is that a common shock affects the interest rate exogenously set by the central bank of the monetary union, that is, the policy interest rate paid by the banks of the area to have access to new liquidity through open market operations or the central bank 'window'. In general, our assumption is that the shock is negative, in the sense that it implies a significant increase in the policy interest rate.[6] The latter leads to an upward shift in the structure of market interest rates; the related increase in the lending interest rate tends to have an adverse selection on banks' borrowers (see Stiglitz and Weiss 1981, Milde and Riley 1988, Ardeni and Messori 1999). Thus, the shock can potentially trigger two consequences in the monetary union: due to the increased cost of their provision and the adverse selection of their borrowers, some of the banks in the different countries can go bankrupt so that the value of their deposits can receive a substantial hair-cut or even decrease to zero (deposit insolvency); as a consequence of the increase in the structure of interest rates, some of the member states can go into a deep recession and can find it advantageous to abandon the monetary union so that their bank deposits are redenominated in the new national currencies.

Differently from Canofari and Messori (2017), we do not model the strategic interactions between the (no-)exit decision taken by a given set of member states and the possible contagion process in the monetary union. Moreover, differently from Canofari *et al.* (2018a and 2018b), we do not analyze the complex relationships between the monetary policy pursued by the central bank and the national fiscal

euro) which characterizes depositors as small. Hence, without any analytical loss of generality, our model can assume that EDIS offers full insurance towards banks' bankruptcy risk to all depositors. It is also meaningless to recall that other member states of the European Union could join the Banking Union in the future. Hence, our model can just refer to a monetary union.

[6] This assumption is a proxy of a restrictive decision taken by the central bank in terms of the monetary policy stance. In this respect, it is worth noting that our model does not analyze how the central bank utilizes the monetary channels to introduce the currency in the economic system.

policies implemented by one or two subsets of member states. We limit ourselves, instead, to focusing on the interactions between a representative national bank and a representative depositor operating in a given member state of the monetary union.[7]

At first sight, the described set-up leads to clear-cut results. When a Centralized Deposit Insurance Scheme (CDIS) is not at work, it is easy to determine a threshold probability level over which the risk of deposit insolvency and/or the redenomination risk make a bank run advantageous for depositors. Hence, it seems quite simple to implement a policy design able to nullify the probability of a bank run: the introduction of a CDIS able to fully protect bank depositors from the risks of banks going bankrupt (see also n. 5). The aim of our paper is to show that this implication is not always true; therefore, our model leads to interesting analytical solutions. However, to build the model and to prove this counter-intuitive result require some further simplifications in the set-up.

In accordance with Miller's paper (2003), we analyze a policy rate shock which has a potential symmetric impact on the *n* countries of the monetary union. As already stated, we generally assume that this exogenous shock implies an increase in the policy interest rate that is large enough to have a recessionary impact on countries' output level and negative impacts on the quality of banks' borrowers as well as on the liability side of banks' balance sheets. Given the assumption of a direct causal link between the policy rate and deposits interest rates, there is also a potential positive effect on depositors' revenue; however, these effects tend to be counterbalanced by the increase in the probability of banks going bankrupt. This last observation points out that it would be interesting to also analyze a potential reduction in the policy

[7] As emphasized by one of the referees, these restrictions imply that our model overlooks important policy problems. However, as shown in the papers just quoted, the examination of the strategic interactions either between national policy makers or between a centralized monetary policy and different national fiscal policies involves difficult analytical points. Hence, an overlap of these latter points with the problems relating to the interactions between central bank, banks and depositors in a country with a possible exit strategy would have required a very complex analytical framework or an oversimplification of banks' and depositors' behavior. Our choice here has been to avoid either an excess of complexity or an oversimplification with respect to the analytical core of our basic model and, in the meantime, to leave the extension of this simple model to future research.

rate with respect to the interactions between banks and their depositors. In fact, in this latter case, the reduction in depositors' unit revenue could make it worthwhile for depositors to hinder banks' expansionary objectives by introducing a binding constraint on the supply of deposits. This would make a depositor free to develop a strategy towards her bank, which in turn would make the link between the policy rate and the deposit rates more complex. However, our model is too simple for analyzing these aspects. In the following of this paper, we rule out any possible strategic behavior on depositors' side.

Being symmetrical, the exogenous shock on the policy interest rate affects each of the *n* countries with the same intensity so that we can refer to a representative small open country *j* (where $j = 1, \ldots, n$). We assume that country *j* is characterized by a stock of government debt significantly above the maximum threshold set by the monetary union rules; hence, the national policy maker cannot implement a countercyclical fiscal policy to offset the increase in the policy interest rate and its consequences. In this framework, to react to the recessionary threat, country *j* only has a radical alternative at its disposal: to exit from the monetary union in order to decrease its exchange rate relative to the other competing member states.[8] This alternative causes different costs for country *j*. To assess the consequent trade-off, it is not necessary to have recourse to an explicit formalization of the working of the rest of the world, since the latter matters only for fixing the foreign interest rate, which could be determined as a weighted average of the non-union interest rates. In accordance with the assumption that the representative member state is a small open economy, country *j* takes this foreign interest rate as a given.

Let us now examine the two different institutional designs of the monetary union which are analyzed in our model (see section 3). The first scenario is characterized by an incomplete banking union where CDIS is not at work; for the sake of simplicity and without loss of generality, we leave out any reference

[8] Obviously, this exchange rate will be always equal to 1 when country *j* choses to remain in the monetary union. Let us add that, in the following model (see section 3), all the variables are in logs Hence, the 'remain' exchange rate of country *j* will become equal to 0 in our model.

to the national insurance scheme on bank deposits.[9] This scenario will be labelled as the "no-CDIS case". The second scenario is characterized by a complete and operative banking union where CDIS is in force; hence, this scenario will be labelled as the "CDIS case". It is obvious that the differences between the two scenarios will become significant when the external shock occurs and affects the policy interest rate, thus increasing the risk of bank bankruptcy and determining the possible exit of country *j* from the monetary union. However, we will show that the "CDIS case" and the "no-CDIS case" do not necessarily lead to opposite 'corner' solutions: "bank run" with no-CDIS and "no-bank run" with CDIS. In a more complex model, this result could imply that the corner solutions are often dominated by the depositor's implementation of a 'mixed' strategy.

To offer an intuition of these outcomes, let us further compare the two cases. In both cases, the policy makers of country *j* have to make a fundamental choice when affected by the shock: remain in or exit from the monetary union.

Let us assume that the expectation of the representative depositor is that the probability of an 'exit' is below the threshold probability that makes a bank run advantageous. In the "CDIS case", the bank run will be avoided for sure since CDIS fully insures the depositor with respect to the negative consequences of the bankruptcy of the representative bank. Any early deposit withdrawal would imply the loss of the revenues offered by deposit holding; and, by assumption, this loss would be higher than the expected loss of the possible deposits' redenomination and its consequences. On the other hand, in the "no-CDIS case" it would be impossible to attribute a zero-probability to a bank run. The absence of CDIS implies that the risk of bank bankruptcy, due to borrowers' adverse selection and the increased cost in the provision of the representative bank, is not covered; therefore, this risk either by itself or added to the

[9] Differently from CDIS, national DISs cannot offer full insurance towards banks' risk of bankruptcy. Hence, in our model, the DISs would just affect once for all the critical level of the threshold over which the risk of deposit insolvency and/or the redenomination risk make a bank run advantageous for depositors.

total sum of the (even if small) probability of the redenomination event and the increased bank's bankruptcy probability conditional to the redenomination event can be significant enough to make a bank run advantageous.[10]

Let us now assume that the expectation of the representative depositor is that the probability of an 'exit' is above the threshold probability that makes a bank run advantageous. The occurrence of a bank run is independent of the working of CDIS. To make this result immediately evident with respect to the "no-exit case", it is sufficient to emphasize two elements. First, the centralized insurance mechanism does not cover the redenomination risk. Second, this mechanism covers the risk of bank bankruptcy under the binding condition that the country is compliant with the rules of the monetary union; and this condition will not be met the moment country *j* exits. Hence, even in the "CDIS case", 'exit' implies that depositors are fully exposed to both the redenomination risk and the consequent bankruptcy risk.

It follows that CDIS would be effective only if the occurrence of country *j*'s 'exit' has a sufficiently low probability, and hence its expected direct (redenomination) and indirect (conditional bankruptcy) negative effects are dominated by deposit revenues. Moreover, CDIS eliminates the possibility that a sufficiently low probability of the occurrence of country *j*'s 'exit' will anyway lead to a bank run due to a sufficiently high probability of being exposed to a (unconditional) risk of bank bankruptcy.

3. The model

This section and the following two sections aim at offering an analytical specification of the results described in Section 2. In this respect, let us start with the definition of a simple benchmark model.

We assume that the policy interest rate i_P depends on a shock ρ_P that makes this interest rate higher

[10] In our scheme, the conditional probability of bank bankruptcy is the probability of this event subject to the probability of country *j*'s 'exit'.

than its equilibrium value i^*. We thus have the following relation:[11]

$$i_P = i^* + \rho_P \tag{1}$$

For the sake of simplicity, we assume that the prices of goods are fixed, and that country *j* produces a single set of goods traded on the national and international markets at a price normalized to 1. We can thus write the aggregate supply for country *j* as:

$$y_j = y_{nj} + \alpha(E_j - E^e{}_j) - \theta i_P - \mu\, C_j \tag{2}$$

where: y_j and y_{nj} are – respectively – the actual and the natural output level of this country; α, θ, and μ are positive parameters capturing the sensitivity of the actual output to – respectively – the variation in the actual exchange rate (E_j) towards its expected value $(E^e{}_j)$, the actual value of the policy interest rate, and the cost of leaving the monetary union (C_j).[12]

It is worth stressing that the causal link between the policy interest rate and the deposit interest rate assumed in the previous section is also applied to the causal link between i_P and the interest rate on the representative bank's lending. Thus, to simplify the notations in equation (2) without any further analytical loss of generality, we omitted the specification of the lending rate as a stable function of i_P and just referred to the latter as an independent variable.[13] It is also worth emphasizing that the cost C_j is a random variable with mean $\bar{C}_j$ and variance σ_j. The latter assumption allows us to capture the stylized fact that the uncertainty relating to the possible exit from the monetary union matters for the stability of the area, and hence affects the policy makers' strategy. This uncertainty would decrease if at

[11] Let us recall that all the variables are in logs. Let us also note that the equilibrium value of the policy interest rate coincides with the value that leads to the stability of the banking sector in country *j*. If the policy interest rate reaches values higher than its equilibrium level, the banking sector will face an increase in the costs of its liquidity provision. Other things being equal, these increased costs imply a higher probability of bank bankruptcy.

[12] To simplify the algebra, in the remaining part of the paper we normalize the parameters by assuming that $\mu = 1$.

[13] The parameter θ can account for this short-cut. Note that we will not adopt the same simplification in the case of the deposit rate (see Section 5 below,), since the latter rate plays a crucial role in our analysis.

least one of the *n* countries belonging to the monetary union implemented the exit strategy (Eijffinger *et al*. 2018, Hefeker and Neugart 2015).

Equation (2) shows that an unanticipated depreciation and/or a decrease in the policy interest rate tend to generate a positive output gap, that is, $y_j - y_{nj} > 0$. As stated above, here we are more interested in the opposite case: a common shock increases the policy interest rate (see equation 1) so that it generates, *ceteris paribus*, a negative output gap, that is, $y_j - y_{nj} < 0$.

Coherently with the abovementioned strand of literature, we can assume as a first approximation that the policy makers of country *j* minimize a quadratic loss function L_j which depends on the following variables: the difference between their output target and the natural output level, the output gap, and the depreciation of the national currency determined by the exit of this country from the monetary union. Note that the policy makers of country *j* aim to achieve an output target higher than its natural level since their internalization of the macroeconomic equilibria is subordinated to the objective of maximizing the national output. Given this specification, the equation to be minimized can be expressed as:

$$L_j = [(y_j - y_{nj}) + (y_{nj} - y_{tj})]^2 + \beta {E_j}^2$$

where: y_{tj} is the output target of country *j*.

A trivial simplification leads to the loss function of country *j*:

$$L_j = (y_j - y_{tj})^2 + \beta {E_j}^2 \qquad (3)$$

Let us now include equation (1) and equation (2) in equation (3), and let us assume that the shared expectation is that country *j* will remain in the monetary union (i.e., ${E^e}_j = 0$). We obtain a new representation of the loss function:[14]

[14] It is worth reminding that the expected value of the square of a random variable is equal to the square of its expected value plus its variance, i.e. ${C^2}_j = {\bar{C}^2}_j + \sigma_j$.

$$L_j = (i^* + \rho_P)^2\theta^2 - 2(i^* + \rho_P)(y_{nj} - y_{tj} + \alpha E_j - \bar{C}_j)\theta + (\alpha^2 + \beta){E_j}^2 - 2\alpha(\bar{C}_j - y_{nj} + y_{tj})E_j + {\bar{C}^2}_j + 2(y_{tj} - y_{nj})\bar{C}_j + (y_{tj} - y_{nj})^2 + \sigma_j \quad (4)$$

where: L_{Ej} denotes the loss function in case of an exit; and $L_j \equiv L_{Ej}$ iff: $E_j \neq 0,\ \bar{C}_j > 0,\ \sigma_j \neq 0$.

The policy makers of country *j* aim at minimizing equation (4) by utilizing the only policy instrument at their disposal, that is, the actual exchange rate of country *j*. In this respect, they face a constraint and have an opportunity. The constraint depends on the fact that a depreciation of the exchange rate causes an uncertain cost of exit from the monetary union. The opportunity derives from the facts that ${E^e}_j = 0$ and the output target of country *j* exceeding its natural output level ($y_{tj} > y_{nj}$); hence, by using the depreciation to increase the actual output, the policy makers of country *j* can exploit the opportunity gains allowed by time inconsistency in monetary policy (see Barro and Gordon 1983).

Let us assume that country *j* decides to leave the monetary union. Given the previous analysis, we obtain the reaction function of country *j* by differentiating equation (4) with respect to the actual exchange rate E_j. Given the exogenous shock on the policy interest rate and other exogenous variables and parameters, we have

$$E^*_{Ej} = \frac{(\theta(i^* + \rho_P) + y_{tj} + \bar{C}_j - y_{nj})\alpha}{\alpha^2 + \beta} \quad (5)$$

This reaction function determines the optimal depreciation of country *j* in case of an exit from the monetary union (where E^*_{Ej} denotes the new equilibrium exchange rate).

To calculate the loss in case of exit, we introduce equation (5) in equation (4). The exit loss function thus becomes:

$$L_{Ej} = \frac{\left(\left((i^*+\rho_P)^2\theta^2 + 2(i^*+\rho_P)(\bar{C}_j - y_{nj} + y_{tj})\right)\theta) + {\bar{C}^2}_j + (-2y_{nj} + 2y_{tj})\bar{C}_j - 2y_{nj}y_{tj} + \sigma_j + y^2_{nj} + y^2_{tj})\beta + \sigma_j\alpha^2\right)}{\alpha^2 + \beta} \quad (6)$$

Let us now assume that country *j* decides to 'remain' in the monetary union. In this case, we would have to put $E_j = 0, \bar{C}_j = 0, \sigma_j = 0,$ in equation (4). It follows that the no-exit loss function facing the policy

makers of this country is now:

$$L_{NEj} = \left(\theta(i^* + \rho_P) - y_{nj} + y_{tj}\right)^2 \tag{7}$$

The comparison between equation (7) and equation (6) highlights the importance of our previous assumption on the distribution function of the cost of exit from the monetary union (C_j). Uncertainty over C_j increases the stability of this union, since it constitutes the factor determining country *j*'s choice to remain in the monetary union in the absence of shocks that affect the policy interest rate. To prove this result, let us compute the difference between equations (6) and (7) under the assumption that no shocks occur on the policy interest rate ($\rho_P = 0$). Equation (4) allows us to state that this difference is positive. Solving the inequality for the level of uncertainty, we obtain:

$$\sigma_j > \frac{(\theta i^* - y_{nj} + y_{tj})^2\alpha^2 - \bar{C}_j\beta(2\theta i^* + \bar{C}_j - 2y_{nj} + 2y_{tj})}{\alpha^2 + \beta} \tag{8}$$

Equation (8) shows that, in the absence of shocks, country *j* would remain in the union even if there was an incentive to depreciate its exchange rate. This is an important result for at least two reasons. First, it differentiates our analysis from the time inconsistency literature started by Kydland and Prescott (1977); secondly, it perfectly fits with the condition of sustainability of a monetary union, defined as the convenience to "remain" given the trade-off between alternative possibilities. We can thus conclude that the time consistency of the equilibrium in a monetary union without shocks requires a minimum level of uncertainty concerning the cost of abandoning the monetary union. The uncertainty concerning the exit cost assures us that, in the absence of exogenous shocks, policy makers do not have any net advantage in exploiting time inconsistency.

4. The role of policy makers

In this section, we suppose that the policy interest rate is always affected by an exogenous and common shock. In the previous section we showed that in such a case: country *j* has a positive incentive to exit in

order to redenominate its currency; there are conditions under which this incentive becomes prevailing; to verify these conditions, the incentive must be compared with the uncertain cost of exit. In the following paragraphs, we aim to show that country *j* will exit and redenominate its currency only if the increase in the policy interest rate associated with the external shock is greater than a certain threshold level u_j. To prove this result, it is necessary to specify the condition under which the policy makers of country *j* are indifferent between staying or leaving the monetary union. This condition is satisfied when $L_{Ej} - L_{NEj} = 0$. Hence, we can calculate the threshold level u_j of the exogenous shock ρ_P that satisfies the latter equality. By means of some algebra, we obtain:

$$u_j = \frac{\sqrt{(\alpha^2+\beta)(\beta\bar{C}^2{}_j + \sigma_j\alpha^2)} + \alpha^2(-\theta i^* + y_{nj} - y_{tj}) + \bar{C}_j\beta}{\alpha^2\theta} \tag{9}$$

Assuming that the condition of indifference leads to a virtuous *status quo ante*, equation (9) determines the maximum level of shock (u_j) on the policy interest rate that makes country *j* remain in the monetary union.

We can refine and strengthen our interpretation of u_j as determined by equation (9) by analyzing the reaction of this shock's threshold level to changes in five significant variables and parameters. To this end, we calculate the partial derivatives of equation (9) with respect to the following independent factors:

$$\frac{\partial u_j}{\partial \bar{c}_j} = \frac{\frac{(\alpha^2+\beta)\bar{C}_j\beta}{\sqrt{(\alpha^2+\beta)(\beta\bar{C}^2{}_j+\sigma_j\alpha^2)}}+\beta}{\alpha^2\theta} \tag{10}$$

$$\frac{\partial u_j}{\partial \sigma_j} = \frac{1}{2}\frac{\alpha^2+\beta}{\sqrt{(\alpha^2+\beta)(\beta\bar{C}^2{}_j+\sigma_j\alpha^2)\theta}} \tag{11}$$

$$\frac{\partial u_j}{\partial \beta} = \frac{1}{2}\frac{\bar{C}^2{}_j\beta + \sigma_j\alpha^2 + (\alpha^2+\beta)\bar{C}^2{}_j}{\sqrt{(\alpha^2+\beta)(\beta\bar{C}^2{}_j+\sigma_j\alpha^2)\theta}} \tag{12}$$

$$\frac{\partial u_j}{\partial \alpha} = -\frac{2\left(\bar{C}_j\sqrt{(\alpha^2+\beta)(\beta\bar{C}^2{}_j+\sigma_j\alpha^2)}+\left(\frac{1}{2}\bar{C}^2{}_j+\frac{1}{2}\sigma_j\right)\alpha^2+\beta\bar{C}^2{}_j\right)\beta}{\sqrt{(\alpha^2+\beta)(\beta\bar{C}^2{}_j+\sigma_j\alpha^2)}\alpha^3\theta} \quad (13)$$

$$\frac{\partial u_j}{\partial \theta} = \frac{-\sqrt{(\alpha^2+\beta)\left(\beta\bar{C}^2{}_j+\sigma_j\alpha^2\right)}+(y_{nj}-y_{tj})\alpha^2-\bar{C}_j\beta}{\alpha^2\theta^2} \quad (14)$$

Equations (10) – (14) relate u_j – respectively – to: the expected cost that country *j* would face in case of leaving the monetary union (equation 10), the variance of this same exit cost (equation 11); the sensitivity of country *j*'s actual output to – respectively – the gap between the actual and expected exchange rate and the depreciation of the actual exchange rate in case of leaving the monetary union (see, respectively, equations 12 and 13); the sensitivity of country *j*'s output to the value of the policy interest rate (equation 14).

It is trivial to verify that the values of equations (10), (11), (13), and (14) meet the expected signs. Given that all the variables and parameters of the first two equations are > 0 and have positive signs, (10) and (11) have the expected positive sign. Given that all the variables and parameters of equation (13) are > 0 and have negative signs, this equation has the expected negative sign. The negative sign also applies to equation (14) since, in our framework, it is always verified that $(y_{nj} - y_{tj})$ < 0. It follows that an increase in the expected exit cost and in the uncertainty of this cost makes the actual exit of country *j* less likely, in the sense that – *ceteris paribus* – the exit becomes worthwhile for this country only above a higher threshold value (u_j) of the exogenous shock. On the contrary, a stronger sensitivity of country *j*'s output to increases in the policy interest rate and to currency depreciation means that this country has become more vulnerable to recessions and that its net export has become more dependent on price competition. The two latter features make the actual exit of country *j* more likely in case of increases in the parameters here analyzed. Hence, a lower threshold value (u_j) of the exogenous shock is sufficient

to make the exit advantageous.

Until now we have neglected the interpretation of equation (12) that relates u_j to the sensitivity of country *j*'s output to the gap between the actual and expected exchange rate of this country. It is apparent that the sign of this equation is positive for the same reasons that apply to equation (10). However, differently from the previous four cases, the economic interpretation of this positive sign is not immediately evident but requires some further comments.

Let us start by recalling an analytical result of our benchmark model: the policy makers of country *j* do not have incentives to cheat in the absence of shocks. As shown in the previous sections, this result has at least three implications: (i) in the absence of shocks, the exit of country *j* from the monetary union is never advantageous (ii) as a consequence of (i), the absence of shocks is a sufficient condition to satisfy the sustainable equilibrium of a monetary union; (iii) the introduction of shocks implies that an unexpected depreciation in country *j* can determine an opportunity gain allowed by time inconsistency. These three implications show that the relation between β and u_j is driven by opposite forces. Points (i) and (ii) suggest that, even in the presence of shocks, policy makers of country *j* are unwilling to recognize that the gains allowed by time inconsistency prevail on the expected exit costs; hence, only higher threshold values (u_j) of the exogenous shock can lead to an exit of country *j* due to increases in its output's sensitivity towards unexpected depreciation. On the other hand, point (iii) suggests that, in the presence of shocks, an increase in this sensitivity improves the opportunity gains of country *j* anyway; hence, the rational choice of policy makers would be to decrease u_j. Here we limit ourselves to acknowledging that the positive sign of equation (12) means that our simple model attributes a more important impact to the combination of points (i) and (ii) than to point (iii). Our intuition is that the

uncertainty concerning the cost of exit plays an important role in this respect.[15]

This provisional conclusion could foster an extension of our stylized framework: the analysis of the impact that the actual exit of country *j* can have on the choices of the other *n-1* countries that belong to the same monetary union. Let us assume that the actual shock (σ_j) is above the threshold level of this shock (u_j), so that country *j* decides to abandon the monetary union. As we already stated in the previous section, the actual exit of country *j* dramatically reduces the uncertainty in the cost of leaving for the other *n-1* countries. Formally, this implies that $\sigma_k \rightarrow 0$ ($\forall\, k \neq j$; where k = 1, 2, …, n-1) so that the threshold value of the shock (u_k) decreases. As showed by equation (11) (see above), this means that a relatively low value of the exogenous shock can generate the exit of a large subset of *n-1* countries from the monetary union when country *j* already exited. The implication is that, if a given member state finds it advantageous to exit, the monetary union will become more vulnerable to a sort of exit-contagion effect that will be transmitted to the other member states.[16]

As stated in Section 2, we will not analytically elaborate this possible exit-contagion (see Canofari and Messori 2017). We are in fact interested in introducing the relationships between banks and their depositors in our previous simple model. More specifically, our extended model continues to refer to a monetary union affected by the exogenous shock already analyzed; however, it also aims to incorporate the possible bank runs as well as the depositors' reactions to country *j*'s decision either to leave or to remain. Hence, in this extended model the depositors would have to take into account two different types of risks and their possible relations: the risk of banks' bankruptcy and the risk of deposit redenomination.

[15] The elaboration on this point would require specific analytical details. The latter are available, even if in a non-conclusive form, upon request.

[16] It is worth noting that this contagion does not seem to fit with the Brexit case. In our framework the dramatic difficulties experienced by the United Kingdom in its process of exiting from the European Union would have to be modelled as an increase and not a decrease in the expected cost of exit for the other member states. A possible explanation of this contradiction is that our simple framework is unable to account for the level of the expected exit cost, which is set exogenously. Moreover, our model does not analyze the exit from the European Union but the exit from a monetary union.

These risks can be affected by the introduction of CDIS. It follows that our extended model aims at analyzing different scenarios characterized by a couple of variables in two different set-ups: bank run vs. no-bank run in the alternative of: exit vs. remain, and the presence of vs. absence of CDIS.

5. Depositors' choices

Let us assume that in country *j* there is a representative depositor who fully utilizes her information to anticipate the working of the national economic system. The objective-function of this depositor is the minimization of her loss function, which captures the tradeoff generated by the increase in the policy interest rate (i_P) determined by the occurrence of an exogenous shock (ρ_P) (see above, equation 1). On the one hand, this increase is "good news" for the representative depositor of country *j*: given that there is a direct and stable link from the policy interest rate to the interest rate on bank deposits (i_d), any increase in the former will determine a proportional increase in the latter, which amounts to an increase in the promised unit revenue of the representative depositor (see equation 15 below). On the other hand, the same increase of i_P is "bad news" since the consequent proportionally higher interest rates on bank's lending and bank deposits lead – respectively - to an adverse selection of bank's borrowers and to higher costs for a bank's liquidity provision. The representative depositor is aware of this "bad news"; consequently, she forecasts an increase in the bankruptcy risk of country *j*'s representative bank, which can lead to substantial hair-cuts or even to a reduction to zero in the values of her bank deposits (deposit insolvency).[17]

[17] In the euro area, there are other and – perhaps – more important variables that explain why an increase in the policy interest rate can have a strong negative impact on the bank bankruptcy risk. In Germany and in several 'peripheral' member states (specifically, in Italy), banks hold a large amount of national government bonds; in France and in a number of other 'core' member states, banks hold a significant amount of fixed-income corporate bonds and structured bonds. All these different types of bonds would record a decrease in their market values if the policy interest rate of the ECB went up. This decrease would imply potential losses in banks' balance sheets: due to the current accounting rules, that part of these losses attributable to bonds 'collected to sell' must be immediately absorbed by the banks' capital. The consequent loss of capitalization, combined with the difficulties to have actual recourse to market recapitalization (on the average, the European banks' rate of

The tradeoff facing the representative depositor can be easily summed up thus: the "good news" generated by the increase in the policy interest rate would imply an increase in the amount of deposits offered by this representative depositor; the corresponding "bad news" would imply that this same depositor starts a liquidation of her bank deposits, which can result in a total withdrawal ("bank run"). This tradeoff can be formalized by means of the loss function (L_d) of the representative depositor in country *j*. A simple form of this function is:

$$L_d = \gamma_1 P_b(i_p, i_d) D - \gamma_2 D i_d(i_p)$$

where the variables denote: *D*, the value of the deposits; i_d, the deposits' interest rate; and P_b the probability of bank bankruptcy. Moreover, the two parameters, $\gamma_1$and γ_2, express the weight that the representative depositor assigns – respectively – to: the probability of bankruptcy, which is directly related to the policy and deposit interest rates; the deposit interest rate, which is directly related to the policy interest rate.

Note that $i_d(i_p)$ is a stable function that could be expressed as $i_d(i_p) = \delta i_p$ (where δ is > 0). For the same reasons, the default probability can be expressed just as a function of the policy rate; specifically, we can assume the following relation $P_b(i_p) = \lambda (i_p - i^*)$.

Hence, we can rewrite the previous loss function L_d as:

$$L_d = \gamma_1 \lambda (i_p - i^*) D - \gamma_2 D \delta i_p \qquad (15)$$

As we have already emphasized, the representative depositor in country *j* fully exploits her set of information even if, by assumption, she cannot strategically interact with the representative bank. This means that this depositor analyzes the expected impact of changes in the independent variables of

return is below the cost of capital), dramatically increases the banks' vulnerability to bankruptcy. Moreover, as shown in the 2011-2012 period and – for Italy – also in the 2015-2017 period, banks' risk of bankruptcy is worsened by the doom-loop between sovereign risks and the banks' weaknesses. Here we do not refer to all these variables since the latter are not included in our stylized models. However, it is useful to keep these variables in the background since an informal reference to them can strengthen our results.

equation (15) on her loss function taking into account the different institutional scenarios. Hence, in the remaining part of this section it is appropriate to refer to the four scenarios that derive from the depositor's choice (bank run or no-bank run), given the combination of two couples of variables: presence or absence of CDIS, and exit or no-exit from the monetary union. Moreover, as we showed in Section 3, the decision to leave or remain in the monetary union is made by country *j* based on the critical threshold which is present in the information set of the representative depositor. This justifies the scenarios analyzed in the following two subsections.

5.1 Exit

Let us start by assuming that country *j* leaves the monetary union since the shock is above u_j, as defined in equation (9). The representative depositor will find it advantageous to activate a bank run only if her possible gains deriving from the increased interest rate on deposits ($i_d D$) in the case of no-bankruptcy of the representative bank do not compensate her expected losses deriving from the deposits' depreciation ($D\ (1+i_d)\ /\ E^*_{ej}$) and from the increased probability of the representative bank's bankruptcy ($P_b(i_p)$). Thus, given that the representative depositor rationally exploits her information and that i_d is a stable function of i_p, the only significant variable in this scenario is the variation of the policy interest rate due to the exogenous shock. It must also be noted that the presence of CDIS is not effective. By choosing to exit, in any case the policy makers of country *j* deprive the representative depositor of the centralized guarantee, which would only apply inside the monetary union. Hence, in this scenario, CDIS does not affect the depositor's behavior.

The previous considerations imply that, given equation (15), the condition for the bank run can be summarized as follows:

$$\left(1-\lambda\left(i_p-i^*\right)\right)\frac{D(1+\delta\, i_p)}{E_{ej}^*}<D \tag{16}$$

where: $1-\lambda\left(i_p-i^*\right)$ denotes the probability that the representative bank does not go bankrupt; and the right-hand side represents the value of deposits fully sold by the depositor before the exit of country *j* from the monetary union (bank run).[18]

Including equations (2) and (5) in (16) and solving for the shock level ρ_P, we obtain the threshold level u_{Eb} $(>u_j)$ that represents the level of the external shock above which there is a bank run:

$$\rho_P > u_{Eb} \equiv \tag{17}$$

$$\frac{(-\lambda\delta i^*+\delta-\lambda)(\alpha^2+\beta)-\alpha\theta+\left\{(\alpha^2+\beta)(\lambda i^*+1)^2\lambda^2-4(\alpha^2+\beta)\left[\frac{1}{2}\alpha(\delta i^*-1)\theta+\delta\left(-\frac{1}{2}i^*(\alpha^2+\beta)\delta-\frac{1}{2}\beta-\frac{1}{2}\alpha^2+(\bar{c}_j+y_{tj})\alpha\right)\lambda+\left(-\alpha\theta+\delta(\alpha^2+\beta)\right)^2\right]\right\}}{2\lambda\delta(\alpha^2+\beta)}$$

The reading of (17) is not immediate. However, this equation specifies those values of the output target, the exit cost, and the equilibrium policy interest rate that, given the values of the various parameters, determine the maximum level of the threshold which will not lead to a bank run in the country *j* that is leaving the monetary union.

5.2 No-Exit

Let us now assume that country *j* does not leave the monetary union since the shock is below u_j, as defined in equation (9). Given that the representative depositor continues to rationally utilize her information, in this new scenario the introduction of CDIS is effective in the sense that it always makes a bank run disadvantageous for the representative depositor of country *j*. It is quite easy to prove that the coexistence of no-exit and CDIS implies that there is no-bank run. Thanks to the full protection offered

[18] For sake of simplicity we assume that the representative depositor can withdraw her deposits without losses, if she moves before country *j*'s exit.

by the centralized insurance scheme with respect to the possible bankruptcy of the representative bank, the representative depositor can always cash the value of her deposits. With reference to the previous equation, (16), her revenue is at least equal to *D* even in the case of the bank's bankruptcy. Hence, given that the probability of the bank's bankruptcy is lower than 1,[19] an early total withdrawal (i.e., a bank run) would have the only effect of decreasing the depositor's expected gains $\left(1 - P_b(i_p)\right)(i_d D) > 0$.[20]

A different conclusion can be drawn from the "no-CDIS case". In this case, the representative depositor continues receiving information that country *j* will not leave the monetary union, so that her deposits will not incur the risk of depreciation; however, in the absence of CDIS, she will have to compare the losses deriving from the possible bank bankruptcy with the lack of the possible gains from the increased interest rate on deposits deriving from an early total withdrawal of her deposits (bank run). Thus, the condition for the bank run is met if:

$$\left(1 - \lambda\left(i_p - i^*\right)\right) D\ (1 + \delta i_p) < D \tag{18}$$

Including equation (2) in (18) and solving for ρ_P, we obtain the following threshold level u_{NEb} $(< u_j)$ that represents the level of the external shock above which there is an incentive for a bank run:

$$\rho_P > u_{NEb} \equiv \frac{1}{2}\frac{-\lambda\delta i^* + \delta - \lambda + \sqrt{(\lambda i^* + 1)^2\delta^2 + (2\lambda^2 i^* - 2\lambda)\,\delta + \lambda^2}}{\lambda\delta} \tag{19}$$

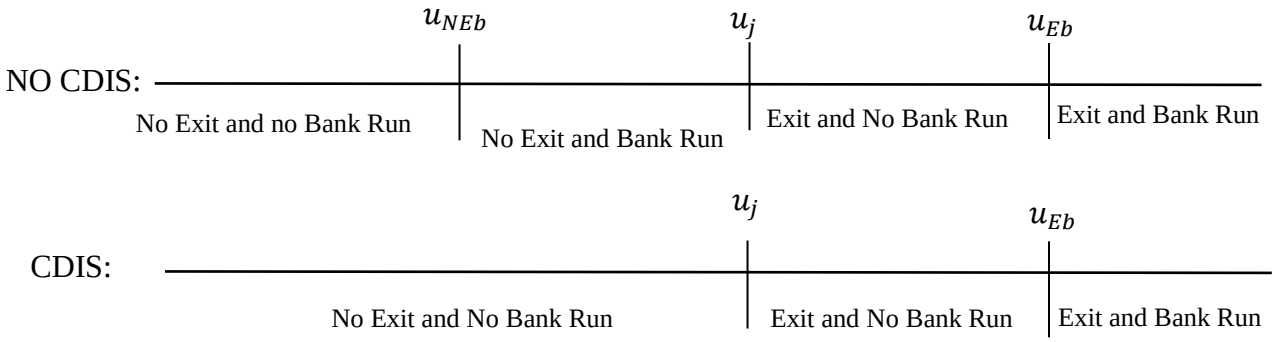
The reading of (19) is not immediate. However, this equation specifies that value of the equilibrium policy interest rate that, given the values of the various parameters, determines the maximum level of the threshold which will not lead to a bank run in the country *j* that is not leaving the monetary union.

[19] This statement is *a fortiori* true since the probability of bank's bankruptcy is directly related to the increases in i_p; and, by definition, the no-exit scenario is based on a moderate external shock affecting i_p.

[20] Our model is too simple to include the time elapsing between the actual occurrence of bank's bankruptcy and the CDIS' actual refund. Hence, in this model the representative depositor does not face a possible loss in the discounted value of her deposits due to the bankruptcy of the representative bank.

Equations (17) and (19), together with equations (5), (7), (16), and (18), allow us to clarify the main results reached in this section by means of a simple Figure in which we specify the thresholds characterizing the possible scenarios in the absence or presence of CDIS.

Figure 1



6. Conclusion

This paper combines the framework developed by Canofari et al. (2015) and Canofari and Messori (2017) with the framework developed by Miller (2003) to offer a theoretical explanation of the role played by a centralized deposit insurance scheme (CDIS) in a monetary union. The main contribution offered by our model to the poor theoretical debate on CDIS is that the impact of this latter scheme cannot be assessed independently of the redenomination risk. CDIS can fully protect depositors from the bank bankruptcy risk inside a monetary union; however, it cannot protect depositors from a country exiting from the monetary union and from the consequent bank bankruptcy risk outside the monetary union.

Our model shows that, despite these limits, the introduction of EDIS has a positive impact on the stability of an economic system. First, the uncertainty characterizing the exit costs implies that the decision to leave a monetary union is never worthwhile in the absence of external shocks on the policy interest rate; hence, in the absence of these shocks, CDIS fully covers the bank bankruptcy risk and thus eliminates

the occurrence of destabilizing bank runs. Moreover, the impact of the external shock does not always imply that some of the member states find it advantageous to leave; the advantage of exiting depends on the shocks' intensity. Hence, the general conclusion is that CDIS mitigates the negative consequences of the banking crisis since it reduces the probability of a bank run. Finally, these results suggest that CDIS weakens the doom-loop between the sovereign crises and the bank crises in a monetary union; if this was true,[21] given the intensity of the external shocks on the policy interest rate, CDIS itself would reduce the probability of a country exiting from the monetary union.

Our stylized model is too simple to provide the abovementioned analytical extensions of the results reached in Sections 4 and 5. These extensions would require the endogenization and the related analysis of the government balance sheets and of the national fiscal policies that we tried to develop in different papers (see Canofari et al. 2018b). Further research could provide a combination of the various frameworks developed in these different papers, which would thus lead to progress in that direction. Moreover, our model is too simple to account for important vulnerabilities in the composition of banks' balance sheets (i.e., the incidence of NPLs and NPEs; the excessive concentration of domestic sovereign bonds) that could affect the probabilities of a bank run and even of a country's exit from the monetary union. This is a possible theoretical drawback with respect to the current policy debate characterizing the euro area. In fact, various economists maintain that the vetoes on the construction of EDIS in the euro area are due to the inability of the most fragile banking sectors to reduce the risks related to their excessive holdings of domestic sovereign bonds; on the other hand, a number of policy makers in the peripheral member states maintain that the actual construction of EDIS would provide for the reduction of these and other risks. To analyze these controversial problems, our model would have to endogenize

[21] It is interesting to note that several European institutions maintain that EDIS is a necessary component of the completion of the banking union since: (i) the main aim of the banking union is to cut the quoted doom-loop; (ii) by decreasing the probability of bank runs, EDIS offers a crucial contribution to overcome this doom-loop.

the behavior of two different representative banks interacting with depositors and policy makers; and this is not an easy task.

We think that these possible extensions are important but are not the immediate steps to pursue in order to strengthen our framework. The model proposed in this paper requires some previous analytical improvements. In this respect, two problems would have to be addressed. First, we suggest that the simplified assumption that depositors have full *ex ante* information on the "exit" vs. "remain" strategy of their national policy makers be overcome. If these depositors suffered from a lack of information on the exit/remain strategy, it would be unjustified to separate the two scenarios deriving from these two strategies and the minimization of depositors' loss function would become more complex and would probably require the implementation of mixed strategies. Second, we suggest the overcoming of the stable relations between the policy interest rate, the lending interest rate and the deposit interest rate, which provide for an indirect but exogenous determination of the structure of interest rates. The actual endogenization of the different interest rates determined by the interactions between banks, firms, and depositors would create space for strategic behavior.

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