Theory and Practice of Contagion in Monetary Unions: Domino Effects in EMU Mediterranean Countries

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Abstract

This paper analyzes strategic interactions and contagion effects in peripheral countries of a monetary union. Using game theory and a cost-benefit analysis, the paper determines the set of equilibrium solutions under which country-specific shocks are transmitted to other member countries giving rise to contagion. Numerical simulations, obtained by a simple calibration of the model on some key Mediterranean countries of the Euro Zone, show the probabilities of contagion from Greece to Spain and Italy.

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1. Introduction

The spectacular increase of sovereign risk premium in the Euro Area following the Greek debt explosion in 2009 and its impact on the sustainability of the European Monetary Union (EMU) have kindled research interest on contagion effects and risk of a systemic crisis in the Euro Zone. The issue has also been of a major concern to European policymakers, and it has brought the containment of systemic financial crises to the center of an international policy debate.

There is now a substantial literature dealing with the European debt crisis, the bulk of it focusing on the role played by fiscal and financial variables in the outbreak of crisis.[1] There are also some recent papers focusing on the role spillover and contagion effects played in exacerbating the sovereign debt problems in the Euro Zone.[2] A major deficiency of this literature is that it still lacks a rigorous theoretical framework to understand the full set of events characterizing the sovereign debt crisis and contagion effects within the EMU. Some exceptions should however be mentioned. Bolton and Jeanne (2011) propose a model of contagious sovereign debt crises in financially integrated economies. Arghyrou and Kontonikas (2012) provide a model of Euro Zone crisis that combines the features of both second- and third-generation approaches to currency crisis. De Grauwe and Ji (2013) present a model of EMU sovereign crisis inspired by the Obstfeld (1996, 1997) model of self-fulfilling-speculative attacks. Canofari *et al*. (2012b) propose a model of crisis and contagion within monetary unions that combines the features of both first- and

[1] See, e.g., Attinasi *et al*. (2009), Barrios *et al*. (2009), Haugh *et al*. (2009), Amisano and Tristani (2011), Bernoth *et al*. (2012), Borgy *et al*. (2012), Aizenman *et al*. (2013).

[2] See, e.g., Caceres *et al*. (2010), Arezki *et al*. (2011), Favero and Missale (2011), Hui and Chung (2011), Arghyrou and Kontonikas (2012), Constancio (2012), De Santis (2012), Gómez-Puig and Sosvilla-Rivero (2012), Metiu (2012), De Grauwe and Ji (2013).

second-generation approaches to currency crisis.[3]

Our paper adds to the above strand of literature by providing a new theoretical framework to understand crises and contagion phenomena within monetary unions. Specifically, we apply game theory and a cost-benefit analysis to study voluntary exits and contagion effects in peripheral countries of a monetary union. The paper looks at two non-core, or periphery, countries of a large union and examines the role of strategic interactions and structural asymmetries in determining the set of equilibrium solutions following a country-specific shock.

The paper is organized as follows. We first discuss the theoretical framework. We then apply the model to the case of Euro Mediterranean countries to assess the probability of contagion under different assumptions about the exit costs. We finally summarize the main results.

2. The theoretical framework

To analyze voluntary exits and contagion effects in a monetary union, we look at a stochastic economy and a currency-union two-stage game where, conditional on the realization of exogenous shocks that cause deviations of the target variables from their preferred level, each member country can either choose to remain in the monetary union or exit by comparing the welfare losses arising from alternative optimal policy in each regimes.[4]

Specifically, we consider a monetary union where two periphery member countries (A and B) strategically interact. Consistent with the second-generation approach, we also include a

[3] A detailed analytical discussion of the basic theoretical approaches to currency and financial crises can be found in Piersanti (2012).

[4] This two-stage approach has been used also for endogenous coalition formation in a monetary union and for monetary union creation (see e.g. van Aarle, 2002, 2003, 2006; Kohler, 2002; Kempf and von Thadden, 2008; Michalak *et al*., 2008). A more formal exposition of this kind of game is provided by Ray and Vohra (1999).

costly escape clause in the policymaker's loss function. The social loss is given by a standard function defined over the output gap and inflation (measured by the change in nominal exchange rate).

Formally, measuring all variables in logs, letting the nominal exchange rate be defined as the price of the foreign currency in terms of the local currency and assuming that prices are fixed for simplicity, we can summarize the model structure by the following equations.[5]

The policymaker's loss function in country i $\left(L_t^i\right)$ is

$$L_t^i = \left(y_t^i - \bar{y}^i\right)^2 + \theta_i \left(s_t^i - \bar{s}^i\right)^2 + \delta\phi^i, i \in \{A, B\}, \tag{1}$$

where y_t^i is date t output and $\bar{y}^i$ the policy maker's output target, taken to be the natural output level; s_t^i is the nominal exchange rate for country i and $\bar{s}^i$ the rate at which the country has joined the monetary union; θ_i is the inflation aversion coefficient; ϕ^i is the opting out cost, assumed to be fixed for simplicity, and δ a dummy variable defined as $\delta = 0$ if country i remains in the monetary union, so that $s_t^i = \bar{s}^i$, and $\delta = 1$ if it exits and $s_t^i \neq \bar{s}^i$.[6]

The aggregate supply for country i is given by

$$y_t^i = a(\Delta s_t^i - E_{t-1}\Delta s_t^i) + \bar{y}^i, \quad i \in \{A, B\}, \tag{2}$$

letting output be a function of the real wage and nominal rigidities be present in the form of a one period wage contract, where Δs_t^i and $E_{t-1}\Delta s_t^i$ denote the actual and the expected change in the exchange rate for country i at time t, respectively.

[5] A more detailed discussion is in Canofari *et al.* (2012a). Similar theoretical structures have been used by Masson (1999), Buiter *et al*. (2001), Berger and Wagner (2005), Canofari *et al*. (2012b).

[6] The cost ϕ may have several sources and could reflect, for example, the loss of international reputation and anti-inflation credibility, voter dissension, or removal from the office.

The international demand for the goods produced in country i, d_t^i, is described by

$$d_t^i = \sigma_i\left[s_t^i - \beta_i s_t^j - (1-\beta_i-\gamma_i)s^W\right] - u_t^i,\ i, j \in \{A, B\} \quad i \neq j, \tag{3}$$

where $\left[s_t^i - \beta_i s_t^j - (1-\beta_i-\gamma_i)s^W\right]$ is the real exchange rate, defined as a trade-weighted variable with weight β_i for the other small periphery country, γ_i for the monetary union, and $1-\beta_i-\gamma_i$ for the rest of the world, s^W is the world exchange rate, assumed fixed for simplicity, and u_t^i is an i.i.d. random shock described by a continuous, bell-shaped and symmetric (around zero) probability density function.

Goods market equilibrium in each country leads to

$$y_t^i = \sigma_i\left[s_t^i - \beta_i s_t^j - (1-\beta_i-\gamma_i)s^W\right] - u_t^i, \quad i, j \in \{A, B\} \quad i \neq j, \tag{4}$$

which can be rewritten as

$$y_t^i = \sigma_i\left(s_t^i - \bar{s}^i\right) + y_t^{i,F} \tag{5}$$

$$y_t^{i,F} \equiv \sigma_i\left[\bar{s}^i - \beta_i s_t^j - (1-\beta_i-\gamma_i)s^W\right] - u_t^i, \quad i, j \in \{A, B\} \quad i \neq j$$

when the two countries join the currency union at a nominal fixed parity $\bar{s}^i$, where $y_t^{i,F}$ denotes the output for country i required to stay in the 'hard' monetary arrangement. The incentive to exit for each country thus comes from the increase in output which can be obtained by a change of the exchange rate.

Notice that, in absence of shocks ($u_t = 0$), the exchange rate parities consistent with a monetary union agreement are endogenously determined in our model. Letting, to simplify algebra, $\sigma_i = \sigma_j = \sigma$, $\bar{y}^i = \bar{y}^j = \bar{y}$, and normalizing the world exchange rate level to one, the required parities can be computed as $\bar{s}_t^i = \dfrac{1}{1-\beta_i}\dfrac{\bar{y}}{\sigma}$, $i \in \{A, B\}$. Under these rates, if no shock occurs at time t, the model implies that the policymakers will have no incentive to *inflate* the

economy to drive output above the private sector preferred level as the output targets coincide. Furthermore, as $y_t^i = y_t^{i,F} = y_t^j = y_t^{j,F} = \bar{y}$ in this case, they will have no incentive to exit and divert from the agreed fixed parities.[7]

To keep things simple we now normalize the output target levels, the world exchange rate and the nominal fixed parities to one[8] and focus on a currency-union game where, following a country-specific shock, each country can choose between two actions: either choosing to remain in the monetary union and set $\Delta s = 0$, denoted by *No exit*, or choosing to leave it and set $\Delta s \neq 0$, denoted by *Exit*. Therefore, the key issue for the authorities is to find the value of the shock at which it is optimal to operate a regime shift. However, as policy decisions are not independent in this setting, an interaction between the policymakers optimizing behavior necessarily develops, and this can lead to multiple equilibria and contagion effects across countries.

The solutions to this game arise from strategy profiles that form a Nash equilibrium. This requires solving first the model to obtain the optimal policies and corresponding losses for each country given the strategy followed by the other country, and then finding the incentive to deviate from it to check if it is or not a Nash equilibrium.

The structure of game allow us to identify four regimes: no countries exit (regime N); only country A exits (regime D^A); only country B exits (regime D^B); both countries exit (regime E). Losses tied to the foregoing scenarios are shown in Table 1.

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[7] It is easy to check that, if $u_t^i = u_t^j = 0$, a rational expectation equilibrium implies $\Delta s_t^i = \Delta s_t^j = E_{t-1}\Delta s_t^i = E_{t-1}\Delta s_t^j = 0$ and $y_t^i = y_t^{i,F} = y_t^j = y_t^{j,F} = \bar{y}$.

[8] Thus, $\bar{y}^A = \bar{y}^B = 0$, and $s^W = \bar{s}^A = \bar{s}^B = 0$.

TABLE 1 -- Payoff Matrix

	No exit	*Exit*
No exit	L_N^A, L_N^B	$L_{D^B}^A, L_{D^B}^B$
Exit	$L_{D^A}^A, L_{D^A}^B$	L_E^A, L_E^B

In the table L_j^i denotes the loss for policymaker i in regime j. The table can be used to find the unique or multiple Nash equilibrium solutions of the game; equilibria are stated formally in the following.

Proposition 1 *Regime* E *is a Nash equilibrium if and only if* $L_{D^B}^A - L_E^A > 0$ *and* $L_{D^A}^B - L_E^B > 0$. *Regime* N *is a Nash equilibrium if and only if* $L_{D^A}^A - L_N^A > 0$ *and* $L_{D^B}^B - L_N^B > 0$. *Regime* D^B *is a Nash equilibrium if and only if* $L_E^A - L_{D^B}^A > 0$ *and* $L_N^B - L_{D^B}^B > 0$. *Regime* D^A *is a Nash equilibrium if and only if* $L_N^A - L_{D^A}^A > 0$ *and* $L_E^B - L_{D^A}^B > 0$.[9]

The alternative losses are computed solving the policymakers' optimization problems in each regime. Under the *Exit* option, optimal policy for country $i \in \{A, B\}$ is obtained by minimizing (1) with respect to s_t^i subject to (4) under $\delta = 1$; otherwise $s_t^i - \bar{s}^i = \delta = 0$ under the *No Exit* choice. The associated reaction functions are

$$\begin{cases} s_t^i = \dfrac{(u_t^i + \sigma_i \beta_i s_t^j)\sigma_i}{\sigma_i^2 + \theta_i} & \text{for } \delta = 1 \\ s_t^i = 0 & \text{otherwise} \end{cases}, \quad i, j \in \{A, B\} \quad i \neq j. \tag{6}$$

Using (1), (4) and (6), the respective losses for country $i \in \{A, B\}$ in all the regimes are:[10]

[9] The proof is straightforward.

[10] Here, L_N^i is the loss of country i when both countries decides to stay in, $L_{D^i}^i$ is the loss of

$$L_N^i = \left(u_t^i\right)^2 \tag{7}$$

$$L_{D^i}^i = \frac{\theta_i}{\sigma_i^2 + \theta_i}\left(u_t^i\right)^2 + \phi^i \ , \ i \in \{A, B\} \tag{8}$$

$$L_{D^j}^i = \left(\frac{\beta_i \sigma_i \sigma_j u_t^j}{\sigma_i^2 + \theta_i} + u_t^i\right)^2 \tag{9}$$

$$L_E^i = \frac{\theta_i\left(\sigma_i^2 + \theta_i\right)\left[\left(\sigma_j^2 + \theta_j\right)u_t^i + \sigma_i \sigma_j \beta_i u_t^j\right]^2}{\left\{\theta_j(\sigma_i^2 + \theta_i) + [(1 - \beta_i\beta_j)\sigma_i^2 + \theta_i]\sigma_j^2\right\}^2} + \phi^i, \ i \neq j \in \{A, B\}. \tag{10}$$

To preserve simplicity and to provide a closed-form solution of the model, we now restrict the attention to the case of symmetry between countries.[11] Thus, we set $\sigma_A = \sigma_B = \sigma$, $\beta_A = \beta_B = \beta$, $\theta_A = \theta_B = \theta$, and $\phi^A = \phi^B = \phi$. With no loss of generality, we also let $u_t^B = 0$, $u_t^A \equiv v_t$, meaning that the shock impacts on country A. Then, using (7)-(10), we find that the threshold values of the shock at which the government is indifferent between opting out and stay in the monetary union are

$$v^* = \frac{1}{\sigma}\sqrt{\left(\sigma^2 + \theta\right)\phi}$$

$$v^{**} = \frac{1}{\sigma} Q \sqrt{\left(\sigma^2 + \theta\right)\phi},$$

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country i when it choices to exit, $L_{D^j}^i$ is the loss of country i when country j decides to exit, and L_E^i is the loss of country i when both countries opt out.

[11] The next section will relax this assumption and extend the model to a heterogeneous monetary union. Numerical simulations computing the probability of contagion across the Mediterranean countries of the EMU will also be shown.

where $Q = \sqrt{\frac{\left(\sigma^4 + \theta\sigma^2\right)}{\sigma^4\beta} \frac{\left[\left(\sigma^2+\theta\right)^2 - \sigma^4\beta\right]^2}{\left[\left(\sigma^2+\theta\right)^2 - \sigma^4\beta\right]^2 - \theta_i\left(\sigma^2+\theta\right)^3}} > 1$, implying $v^{**} > v^*$.[12]

We can state the main implications of the model under a country-specific shock in the following

Proposition 2 (Exit and contagion) *Country A exits the monetary union and devalues if and only if* $v_t > v^*$*; both policymakers exit and devalue (contagion) if* $v_t > v^{**}$.

Proof. See Appendix.

The interpretation underlying Proposition 2 is straightforward. If the shock is small, the stability of monetary union is preserved. A medium-size shock provides incentive to devalue only for the affected country. If the shock is large enough to be above a threshold value, contagion is observed. The proposition also suggests that both multiple equilibria and the perverse case, where only the country not hit by the shock chooses to exit, cannot occur.

3. Domino effects in Euro Mediterranean countries

This section focuses on contagion risks in EU Mediterranean countries. We look at an heterogeneous-country version of our model and examine the domino effects of an idiosyncratic shock hitting Greece (G), to estimate the probability of contagion to Spain (S) and Italy (I).

In order to perform numerical simulations, we make use of a simple parameterization of

[12] Note that $Q > 1$ as long as β is smaller than one. The first term under the root is larger than one; the second term is always larger than one for admissible values of parameters.

our model under different assumptions about the exist costs. Specifically, we relied on estimates provided by Canofari *et al*. (2012b) for Euro Zone countries over the period 1980Q1-2010Q3 for the elasticity of aggregate demand to real exchange rate (σ), and on estimates obtained by Krause and Méndez (2008) from a panel of 34 countries over a period of 24 years for the inflation aversion coefficient (θ).[13] Moreover, we computed the weight coefficients for trade, β, as

$$\beta_i^j = \frac{\Pi_i^j}{\Pi_i^{EU}}, \; i, j = \{G, I, S\}, \tag{11}$$

where Π_i^j measures the volume of international trade (sum of exports and imports) of country i with respect to country j, and Π_i^{EU} the volume of international trade of country i in the Euro Area.

The parameterization for the baseline calibration is summarized in Table 2.

TABLE 2 – Calibration

Country i	σ_i	θ_i	β_G^i	β_i^G
Greece (G)	4.97	2.10	_	_
Italy (I)	1.22	3.77	0.22	0.02
Spain (S)	2.87	3.34	0.07	0.01

Simulations were also based on the following hypotheses. We let the random shock in Greece to be normally distributed with zero mean and standard deviation equal to that of the Greek output gap over the period 2000-11.[14] We included different values for the opting out costs. Specifically, we first computed the lowest (ϕ_{min}) and the highest (ϕ_{max}) cost by fixing the

[13] Average inflation aversion coefficients over the period 1981-1997 were considered.

[14] Greek potential output was obtained by applying the Hodrick-Prescott filter.

probability of contagion and domino effects exogenously at 35% and 5%, respectively.[15] Then, we added three intermediate cost value from a convex combination of the above maximum and minimum cost namely,

$$\phi = \chi\phi_{max} + (1-\chi)\phi_{min}, \quad \chi \in [0.75, 0.50, 0.25].$$

The ensuing five scenarios are shown in Table 3. The results reveal that the probability of contagion from Greece to Spain is higher than the probability of contagion to Italy. Hence, if Italy exists due to contagion from Greece, Spain will also exit, but the reverse does not necessarily hold. They also show that the highest probability of a full domino effect (35%) attains at the lowest opting out cost.

TABLE 3 – Domino Effects

Scenarios	Cost cases				
	1	2	3	4	5
No contagion[16]	30.57%	30.59%	30.62%	30.65%	8.02%
Spain contagion	14.27%	17.41%	21.43%	28.22%	6.94%
Italy and Spain contagion	5.00%	7.53%	11.61%	20.54%	35.00%

Note: 1 (resp. 5) denotes the highest and lowest cost case; 2,3 and 4 are the intermediate cost cases.

4. Conclusions

In this paper we have used game theory and a cost-benefit analysis to model contagion and domino

[15] Calculations involved the following two equations: $\int_{v^{**}}^{\infty} \frac{1}{\sqrt{2\pi s_G^2}} e^{-u^2/2s_G^2} du$ and $v^{**} = Q\sqrt{(\sigma^2+\theta)\phi}/\sigma$, where s_G^2 denotes the variance of the Greek output gap. Notice that the equation for v^{**} refers to the symmetric case. The expression for the asymmetric case is too muddy to be displayed here. The required computations and mathematical expressions are however available upon request.

[16] Only Greece exits.

effects in a simple monetary union. Investigating the effect of a country-specific shock, we have found that: i) small shocks do not affect the stability of monetary union; ii) medium-size shocks provide incentive to devalue only for the country hit by the shock; iii) contagion and domino effects can occur only for large shocks.

Numerical simulations, obtained by a simple model calibration on EMU Mediterranean countries, provided the empirical support to the above theoretical implications. We computed probabilities of contagion under different scenarios. Moreover, we found that if Greece leaves the EMU, a possible contagion to Italy also implies a contagion to Spain, but not vice versa.

Appendix – Proof of Proposition 2

Proof. Write the incentive to move between alternative regimes in a compact form as: $a_1 = L^A_{D^B} - L^A_E$, $a_2 = L^A_{D^A} - L^A_N$, $b_1 = L^B_{D^A} - L^B_E$, $b_2 = L^B_{D^B} - L^B_N$. Thus, if $a_2 > 0$, for example, country A has no incentive to leave the monetary union. Setting $u^B_t = 0$, it is easy to check that

$$a_1 > 0 \Leftrightarrow v_t > v^{***} \tag{12}$$

$$b_1 > 0 \Leftrightarrow v_t > v^{**} \tag{13}$$

$$a_2 > 0 \Leftrightarrow v_t < v^{*} \tag{14}$$

$$b_2 > 0 \text{ always}, \tag{15}$$

where $v^* = \frac{1}{\sigma}\sqrt{\left(\sigma^2+\theta\right)\phi}$, $v^{**} = Q\ v^*$, $v^{***} = \frac{\beta_i\sigma^2}{\sigma^2+\theta}v^{**}$. As $Q>1$, $v^* < v^{**} > v^{***}$.

Accordingly, from proposition 1 and (12)-(15), it follows that: i) E is a Nash equilibrium if and only if a_1 and b_1 are both positive, i.e. $v_t > \max(v^{**}, v^{***}) = v^{**}$; ii) Regime N is a Nash equilibrium if and only if $a_2 > 0$ and $b_2 > 0$, i.e. $v_t < v^*$; iii) regime D^B is never a Nash equilibrium as it would require $b_2 < 0$.

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