New perspectives on the international lender of last resort after the recent financial crisis

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Abstract

The dollar shortage suffered by the European banking systems in 2007-2008 was overcome thanks to the swap lines by the US central bank granted to the European banking systems to overcome the dollar shortage and reduce the risk of default. Emerging countries dealt with the dollar shortage by turning to the ample currency reserves they had at their disposal. What happened re-opened the debate about the International Lender of Last Resort. On the one hand, contrary to what has been shown by a vast literature, the recent crisis has demonstrated that the IMF lacks a fundamental requisite for being an ILOLR, that is to say, the capacity to create money. On the other hand, various emerging countries are unwilling to accept the drawbacks connected to the Fed performing the function of an ILOLR. The FED, however, plays the role of international ILOLR taking into consideration the protection of the interests of its country. In this context, other countries should escape the state of dependency by the Fed and the uncertainty of its behavior by introducing new regulations to reduce the foreign currency liquidity risk.

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Keywords: 2007-08 financial crisis, European banking system, dollar shortage, swap lines, international lender of last resort, foreign currency liquidity risk.

1. Introduction

There has been a broad debate on the link between global imbalances and the financial crisis of 2007-2008. The main contributions to this debate tend to attribute such a link to current-account imbalances, which are significantly negative for several advanced economies and markedly positive for various emerging and oil-producing countries. In line with the most recent contributions, Section 1 of this paper shows that the recent global financial crisis was preceded not so much by a widening of current-account imbalances as by a pronounced increase in gross capital flows between countries. In particular, there was a marked increase in inflows and outflows, not so much from countries with current account surpluses as from the advanced countries. In particular, between 2002 and 2007 several banks of major European countries dramatically increased their long-term assets in dollars, especially ABS, stocking up on short-term funding on the interbank market or the money market.

When the financial crisis occurred and rarefied the supply of dollars in the money market and interbank markets these banks experienced increasing difficulties in rolling over their short-term liabilities in US dollars. These banks were led to apply for refinancing in the form of swap lines from the Fed. In Section 2 we point out and discuss the factors leading to this move.

What led the US central bank to provide liquidity in U.S. dollars to banking systems with problems of rolling over debt in a short period? This question is addressed in section 3 with the aid of an analytic model. In order to deal with a shortage of the foreign currency of a country “B”, the banks in a country “A” may resort to fire sales that inflict losses on many institutions. In case of high interconnectedness of these banks with those of country “B”, these losses can favor forms of contagion leading to a financial crisis in both countries. The central bank of country “B” can prevent this situation acting as an ILOLR. In this way, the central bank of country “B” produces the public good of international financial stability. However, it is led to do so by the primary concern to safeguard the stability of its domestic banking system.

Empirically what occurred during the financial crisis of 2007-2009 highlighted a dichotomous situation. The countries with banking systems closely intertwined with the U.S. benefited from the refinancing interventions of the Fed. The “peripheral” countries, or those only slightly intertwined with the US, had to rely mainly on the foreign exchange reserves at their disposal.

The granting of swap lines by the Fed allowed the European banking systems to overcome the dollar shortage and reduce the risk of default. The effects of these refinancing operations are

illustrated by the use of econometric tests in Section 4. The results of these tests confirm that the provision of swap lines from the Fed reduced the illiquidity and credit risk of banking systems with serious problems of U.S. dollar shortage.

1. Gross capital flows and dollar shortage

As shown by several scholars[1] the increase in gross capital flows to the United States in the early part of the last decade is not so much linked to the performance of the current account balance of the United States but rather to the increasing financial integration of economies.

In 2007, 54.7 per cent of capital inflows to the U.S. came from advanced countries, while only about 25 per cent came from the countries of South-East Asia and the major oil-producing countries, that is from countries with a huge current account surplus (Table 1).

Table 1 – Gross financial inflows and outflows to and from the United States(1) in 2007 (in billions of US dollar)

Countries	Inflows	Outflows
Europe	1015.9	1014.0
Euro Area	360.3	477.2
United Kingdom	561.0	422.4
Asia and Pacific	450.0	26.8
China	260.3	-2.0
Japan	65.9	-50.0
Taiwan	5.8	-2.8
Singapore	20.9	14.0
Australia	-0.2	27.3
Canada	83.5	67.9
Middle East	39.8	13.6
OPEC	52.1	19.2
Others	488.2	330.6
Total	2129.5	1472.0

Source: Bureau of Economic Analysis. (1)Excluding financial derivatives.

[1] See among others Borio and Disyatat (2011).

Table 1 also shows that, differently from emerging countries, for Europe and Canada the amount of inflows and outflows from the US is substantially equivalent.

It is also to be noted that in the period between 2003 and 2007, unlike the countries in surplus, whose purchases of U.S. assets consisted mainly of Treasuries and Agencies, European countries acquired corporate debt securities (Figure 1): they bought about two-thirds of the foreign purchases of corporate debt and about half of foreign purchases of ABS.[2]

To finance their investments in U.S. dollar assets, European countries relied heavily on wholesale funding.[3] Unlike what happened in the surplus countries, in the pre-crisis period the European financial systems engaged in the risky activity of maturity transformation, exposing themselves to a high risk of illiquidity. In mid-2007 the U.S. dollar funding gap of the European banking systems reached 1 to 1.3 trillion dollars. About half this gap was covered by European banks through FX swaps and the remainder by resorting to money market funds, by using the interbank market and by borrowing from central banks.[4]

As is known, in the summer of 2007 the U.S. money market started to deteriorate severely. As a result of the growing concern of investors about the quality of assets held by SIVs, the possibilities European banks had to fund through the placement of ABCP were drastically reduced.

The diminished possibilities of funding in dollars through ABCPs led non-US banks with roll-over problems to increase their demand for liquidity on the U.S. interbank market. This caused severe tensions in this market. A further contributing factor, besides increased demand, was changes in supply behaviour. This shrank dramatically both because of the emergence of forms of liquidity hoarding and due to banks' diminished willingness to provide funds on the interbank market.[5] This inevitably led to tensions on the interbank market. The spread between LIBOR and OIS, which

[2] As noted by Bernanke *et al.* (2011) with reference to these countries: "... the rise in claims included significant amounts of asset-backed securities and other complex financial instruments, whereas the rise in liabilities was tilted toward traditional securities and bank deposits". See also Bertaut *et al.* (2011).

[3] Acharya and Schmabl (2010) provide a detailed description of how the European banking systems operated. Commercial banks were creating security investment vehicles (SIVs) to hold AAA-rated assets backed by subprime mortgages. In turn, the SIVs were financed largely by placing asset-backed commercial papers (ABCP) mainly in money market funds. In some cases, as with the German Landesbanken, the ABPCs were explicitly or implicitly guaranteed by the government. In addition to ABPCs, the European financial systems financed their assets in dollars using the interbank market and foreign exchange swaps.

[4] See, in particular, McGuire and Von Peter (2009).

[5] See Taylor and Williams (2009) and Brunnermeier (2009).

reflects the risk premium on interbank term loans (prior to August 2007 it was close to zero), from that month onwards rose to exceed 50 base points. It remained on this level until September 2008.

When non-US banks found it difficult and expensive to borrow on the U.S. interbank market, they tended to resort to foreign exchange swaps. However, since demand for national currencies of these banks, in particular of euros, by U.S. banks was lower than the demand for dollars by non-US banks, *in primis* by European banks, there was a severe imbalance between supply and demand of USD swaps and a marked increase in the cost of borrowing in USD by non-US banks.

Things became worse after the collapse of Lehman Brothers in September 2008 and the spread of insolvency in the sub-prime mortgage sector.[6] During the latter part of 2008, the spread between LIBOR and OIS increased significantly. Similarly, there was a significant increase in the premium on swaps.

Roll-over problems were particularly marked for the European banking systems, given both their extensive short-term liabilities in U.S. dollars and the large foreign currency liquidity risk to which they were exposed.

It is not surprising, therefore, that as early as the autumn of 2007, but especially after the collapse of Lehman Brothers, the spread between the eurodollar rate and the U.S. dollar LIBOR increased significantly. This point suggests that on account of the increased cost of roll-over funding in U.S. dollars the creditworthiness of many non-US banks, in particular of European banks, worsened significantly.

Evidence of this can be found in the trends of banks' CDS in the countries that resorted to the dollar swaps provided by the Fed between 2007 and 2009 in favour of various central banks and which will be discussed in more detail in the next section.

To this end, reference is made to a sample of 23 countries, 12 of which belong to the eurozone, a further five European countries (UK, Switzerland, Denmark, Sweden and Norway), Japan, the United States and the only four emerging countries that have benefited from the swap lines with the Federal Reserve (Brazil, Mexico, Korea and Singapore).

To try to assess the factors that have influenced changes in the creditworthiness of the banks we looked at the prices of the 5-year CDS of the banks of the countries applying for swaps,[7] at the data

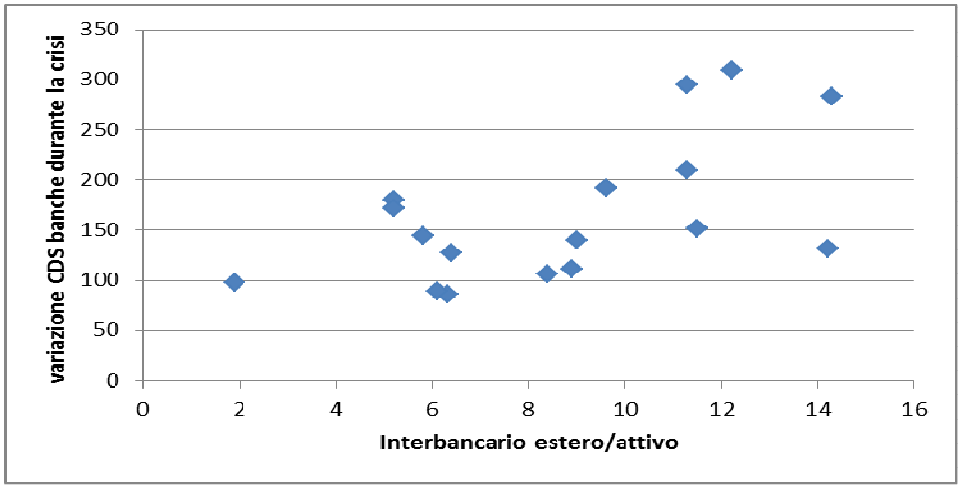
[6] BIS (2008).

[7] Source of data: Datastream. More precisely, we considered the CD prices for 42 banks; this enabled us to calculate the average value of the banking systems of 17 of the 23 countries considered.

on the share of interbank liabilities towards foreign banks in relation to total assets, for the different banking systems included in the sample.[8]

Given the small sample size,[9] what we offer here is not an econometric analysis, but only a chart representing the relationship between the share of the foreign interbank market and the deterioration of the creditworthiness of the banking systems considered (Figure 1).

Figure 1 - Use by the banks of the foreign interbank market and creditworthiness



Source: Datastream.

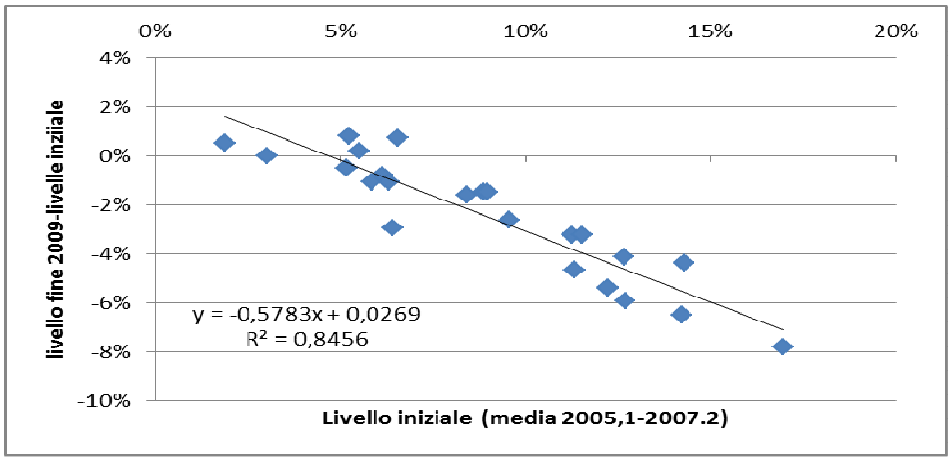
The chart makes it fairly clear that, between 2007 and 2008, the deterioration in the creditworthiness of one banking system compared to another was significantly affected by the greater or lesser fragility of its liquidity conditions, as expressed by the share of the foreign interbank system in relation to banks' total assets: "It should be emphasized that cross-currency funding and cross-border banking per se should not be seen as the main problem in this episode. Rather, it was the inadequate recognition and management of the risk involved – in particular, with

[8] We used the BIS database relative to consolidated banking statistics of the foreign liabilities of banks on ultimate risk basis. For the total assets of the European countries we used ECB statistics, for other advanced countries we referred to the statistics of the relevant central banks and for the four countries in the developing world we used IMF statistics.

[9] We have only been able to reconstruct the data for 17 countries. Given this, the bivariate relationship between the two variables is highly significant, as is the relationship between the two variables once the change in the creditworthiness of the relevant sovereign bond has been taken into account.

regard to the reliance on short-term funding and exposure to potentially illiquid assets – that posed a threat to the stability of the system."[10]

Figure 2 - Share of the foreign interbank system and its variation



It is not surprising, then, that the various banking systems have seen fit to "catch down" to try and increase investor confidence in their solvency.[11] Indirect confirmation of this can be seen in the almost perfect negative relationship between the initial levels of the impact of foreign debt on assets and its variation during the crisis (Figure 2).

The consequences of a shortage of liquidity in foreign currency for the solvency of banks and possible related contagion effects can be illustrated in a formal model. This model allows us to identify ways of preventing currency shortage and how it can possibly be dealt with in order to avoid the situation degenerating into a large-scale financial and currency crisis.

2. Demand for US dollar *swap lines*

The banking systems with high maturity mismatching between assets and liabilities in dollars were able to deal with the roll-over problems of their short-term debts in dollars in the following ways:

[10] See CGFS (2010; p. 11).

[11] In this case we took into account the data for the entire sample of countries under consideration.

i. By resorting to forms of re-financing in US dollars through national central banks. This course of action was possible only if the country had sufficient currency reserves. On the other hand, given the low yield of the assets in which they are held, having currency reserves brings with it inevitable costs for the economy.

ii. By refinancing in national currency through the country's central bank and selling local currency to purchase US dollars on the open market. This course of action would inevitably bring with it a lowering of the exchange rate. This would lead to a currency and financial crisis, as happened in the Asian crisis of 1997-98.

iii. By selling off long-term assets in dollars. In this case, the banks would incur "heavy losses since these assets are likely to be sold at fire sale prices".[12] Such serious losses could compromise the stability of the banking system and had a contagious effect at an international level.

iv. By obtaining from the US central bank credit lines in dollars. This course of action would lead to close cooperation between central banks and, in particular, the decision by the Fed to meet demand for short-term loans in US dollars from other central and to assume the risk that the financed states might default.

The alternative set out in point *iv*. was the one adopted by the advanced economies, as shown in Table 2. The ECB, the Bank of Japan and the Bank of England were the central banks that made the largest withdrawals on the reciprocal currency arrangements. The ECB and the Bank of Japan reached a peak of use of $ 291 billion and $ 122 billion, respectively, in December 2008, while the Bank of England hit a peak of $ 74 billion in October 2008.

With the gradual return of the US money market to normal conditions and the diminishment of the dollar shortage, the number of FX swaps lines granted by the Fed declined rapidly in the first half of 2009, and reached zero in early February of 2010 (Table 2).[13]

[12] See ??

[13] Contrary to the provisions of Bagehot, the conditions applied by the Fed to FX swap lines were not penalized in any way. On the one hand, they did not involve any exchange rate risk, since the exchange rate at which central banks would have to buy back its currency by the Fed was the same as when they drew on its swap line. On the other hand, the interest rate applied to the FX swap lines was that applied to its domestic lending operations.

Table 2 - Drawing of swap lines by Fed (millions $).

End of quarters	2007-4	2008-1	2008-2	2008-3	2008-4	2009-1	2009-2	2009-3
ECB	20,000	15,000	50,000	174,472	291,352	165,717	58,899	43,662
Switzerland	4,000	6,000	12,000	28,900	25,175	7,318	369	-
Japan	-	-	-	29,622	122,716	61,025	17,923	1,530
UK				39,999	33,080	14,963	2,503	13
Denmark				5,000	15,000	5,270	3,903	580
Australia				10,000	22,830	9,575	240	-
Sweden					25,000	23,000	11,500	2,700
Norway					8,225	7,050	5,000	1,000
Korea					10,350	16,000	10,000	4,050
Mexico							3,221	3,221
Total	24,000	21,000	62,000	288,263	533,728	309,918	144,585	56,576

Source: Federal Reserve Bank of New York.

In order to ascertain the variables that affected the demand for swap lines with the Fed we have regressed the percentage amount of these transactions on the foreign reserve assets of each country (SWAP / RES),[14] the share of the foreign interbank system on GDP (FOR / GDP) or on reserves (FOR / RES), the share of the banks' official reserve on total banking assets (RES / ASS) and of the latter on GDP (ASS / GDP). Since the Fed took action only after the consequences of the dollar shortage had manifested themselves, while the number of SWAP transactions refers to the average of 2008, all other variables refer to averages of the pre-crisis periods.[15]

The results of the estimates show that, despite their different specifications (Table 3):

a. the greater exposure of banks on the foreign exchange interbank market is associated with a greater demand for U.S. dollar swaps with the Fed. The size of this causal factor is significant in that a standard variation of the indicator of liquidity tension determines a variation of demand between 35 and 70% of the average of the dependent variable.

b. as expected, high amounts of reserves reduce the need to resort to swaps;

[14] The dollar swap operations with the Fed and the level of official reserves are taken from the BIS "DataTemplate on International Reserves and Foreign Currency Liquidity".

[15] More precisely, the reserves are valued in the last quarter of 2007, while the assets and the foreign interbank market have as a reference the average of the period from the first quarter of 2005 to the second quarter of 2007.

c. the size of banking systems relative to the size of the relevant country's economy favours greater demand for dollar liquidity.[16] The demand of swap lines has been particularly high in the advanced economies and in countries with a highly developed financial market.

Table 3 Incidence of SWAP operations on official reserves

Variabile	Ver1	Ver2	Ver3
C	0.053	0.044	-0.001
	(0.049)	(0.051)	(0.041)
FOR/GDP	0.799**	0.647**	
	(0.140)	(0.143)	
RES/ASS	-0.449**	-0.366**	
	(0.133)	(0.122)	
ASS/GDP			0.051**
			(0.010)
FOR/RES			0.002**
			(0.000)
DUATBE		0.403**	0.530**
		(0.045)	(0.017)
R2c	0.58	0.84	0.87
S.E.	0.153	0.095	0.085
N. Obs	21	21	21

Legend: *significance at 95%; ** significance at 99%

What is set out in point *a* is confirmed by the fact that the OECD countries with the greatest exposure in the short term in US dollars are those that used more swap lines: This is clearly evident from a comparison of Tables 1 and 4.

What is described in point *b.* explains why, as shown by Obstfeld *et al.* (2009; p. 484), "for every advanced country except Japan the size of the swap exceeded 50 per cent of actual reserves held and in the case of the UK, Australia and the ECB, the swap was larger than existing reserves … In contrast, the swaps to emerging countries are never larger than 50 per cent of their actual reserves".

[16] In the analysis of residuals what is significant is the error for the Austrian and Belgian banking systems in particular situations (Austria was affected by considerable exposure to eastern European countries, Belgium by the liquidity crisis of the country's largest banking group) resulted in severe liquidity strains: for this reason the introduction of a joint dummy for these countries (DUATBE) results in a significant improvement of the fit of the regression.

Table 4 – Short term claims of US banks on OECD economies ($ US millions)

Destination of Funds	2007Q4	2008Q1	2008Q2	2008Q3	2008Q4
Austria	4179	4207	4841	3537	2256
Belgium	8742	13911	17453	15630	15567
Czech Republic	527	716	798	894	518
Finland	3191	2837	2386	3024	2928
France	57952	69098	41790	43719	55287
Germany	56910	65933	48407	40111	39266
Greece	3947	4857	3005	2164	2428
Hungary	894	1003	900	1113	491
Ireland	28317	27471	28082	27357	23550
Italy	25180	25521	26215	17012	17243
Korea	26254	27435	28027	29873	21518
Luxembourg	26050	24730	22826	21398	11943
Mexico	6492	7752	7497	6574	7734
Netherlands	43132	46995	52071	45699	37230
Poland	2356	2254	2279	2308	2521
Portugal	2861	2331	2054	1549	1226
Spain	28267	28367	25370	15853	18420
Turkey	7320	6916	7014	6009	5107

Source: BIS International Banking Statistics

3. The supply of swap lines from the Fed

The situation of dollar shortage that plagued other banking systems, particularly those of the eurozone, was significantly alleviated by the swap lines provided by the Federal Reserve to other central banks since the end of 2007.

Between December 2007 and mid-September 2008, the swap lines granted by the U.S. Federal Reserve were essentially an extension of the TAF.[17] After the failure of Lehman Brothers, the Fed increased both the number and total of FX swap lines. Before 15 September the Fed granted FX swaps lines to a total of $ 67 billion. This went up to $ 247 billion on September 18 and reached $ 620 billion on September 29 (Table 4).

In mid-October 2008, the Fed removed all limits on swap lines to the ECB, the Bank of England, the Swiss National Bank and the Bank of Japan.

[17] See Fleming and Klagge (2010).

Table 4 – Timeline of Dollar swaps Announcements

Date	Event	New participants	Total authorization (US bn)
December 12, 2007	Establish dollar swap with ECB ($20 bn) and SNB ($4 bn); 28-day auctions; agreement for 6-months		24
March 11, 2008	Expands lines with ECB ($30 bn) and SNB ($6 bn)		36
May 2, 2008	Expand lines with ECB ($50 bn) and SNB ($12 bn)		62
July 30, 2008	Expand lines with ECB ($55 bn)		67
September 18, 2008	Expand lines with ECB ($110 bn) and SNB ($27 bn).	Establish facilities with BOJ ($60 bn), BoE ($40 bn), BoC ($10 bn)	247
September 24, 2008		Establish swap with RBA ($10 bn), Danmarks Nationalbank ($5 bn), Sweden Riksbank ($10 bn), Norges Bank ($5 bn)l	277
September 26, 2008	Expand lines to ECB (($120 bn) and SNB ($30 bn)		290
September 29, 2008	Expand ECB ($240 bn), SNB ($60 bn), BOC ($30 bn), BOE ($80 bn), BOJ ($120 bn), Danmarks Nationalbank ($15 bn), Norges Bank ($15 bn), RBA ($30 bn), Riksbank $30 bn).		620
October 13, 2008	Expand ECB, SNB, and BOE: no pre-specified limit		
October 14, 2008	Expand BOJ: no pre-specified limit		
October 28, 2008		Extend $15 bn swap line to RBNZ: no pre-specified limit	
October 29, 2008		Extend $30 bn swap line to Brazil, Mexico, Korea, Singapore: no pre-specified limit	
February 3, 2009		Extend swap agreements until October 30, 2009	
June 25, 2009		Extend swap agreements until February 1, 2010	
February 1, 2010	Swap agreements expire		

What prompted the Fed to grant such large a number of swap lines, in other words, to act as a quasi-ILOLR?

A possible explanation for this behavior is that the American central bank was driven by the concern that the banking systems of the countries afflicted by dollar shortage would sell off their long-term assets in US dollars.

This would have inevitably had negative repercussions on the market price of these assets. The consequent losses could have led to numerous banks defaulting, making them unable to repay short-term debts to American financial institutions. This would have had contagious effects of the American banking system.

This situation can be represented formally by extending to two countries the pattern proposed by Acharya *et al.* (2012). Consider a game between the Fed and the market. The framework consists of two countries, the country A and the country B; both countries have a well-developed financial market. Each country has a bank. Events happen on four dates: t=0,1,2,3. On date 0 both banks have an endowment of risky assets. On date 1 the A's bank needs some refinancing. If it cannot find a loan, it will be obliged to sell some assets. On date 2 it is the B's bank that needs refinancing. If the A bank in period 1 sold some assets, the value of the B assets lowers. The goal of B's central bank is to minimize the cost of refinancing B banks. It can intervene at two moments: it can refinance A and B banks or it can refinance only B banks.

<u>The A bank</u>:

At *t*=0 the A bank has a continuum of measure (1-l) of risky assets and l of liquidity. At t = 3 the risky assets yield a random return equal to $\tilde{R}$ with $\tilde{R} \in (0, R)$. At t=1 the A bank needs refinancing of ρ^A units of cash per unit of risky assets. If assets are not refinanced, $\tilde{R} = 0$. If they are refinanced, the return is $\tilde{R} = R$ with probability *p*, and $\tilde{R} = 0$ otherwise. The A bank can affect the probability *p* by monitoring its assets at t=1: $p=p_H$ if it monitors, and $p=p_L=p_H-\Delta p$ otherwise, with $\Delta p>0$. Monitoring is non-verifiable and if it does not monitor, the bank enjoys a private benefit *b* per unit of assets. We assume it is efficient to refinance assets only if they are monitored:

(1) $$p_H R \geq \rho \geq (p_L R + b)$$

In the market there is enough excess liquidity to fund the A bank's assets. Liquidity can be transferred in two ways: the A bank can borrow from the market or sell some of its assets.

Borrowing

Due to limited liability, moral hazard in monitoring limits the A bank's borrowing capacity. The bank can receive a loan L against a repayment equal to *r* if $\tilde{R} = R$ and equal to 0 if $\tilde{R} = 0$.

The A bank chooses to monitor its assets only if $(1-l)p_H R - p_H r \geq (1-l)[(p_H - \Delta p)R + b] - (p_H - \Delta p)r$. The incentive compatibility constraint requires the repayment *r* to be small enough, i.e.:

(2) $r \leq (1-l)(R - R_B)$ with $R_B \equiv \frac{b}{\Delta p}$.

The A bank's borrowing capacity conditional on monitoring is:

(3) $L = p_H(1-l)(R - R_B)$

Asset sales

Each unit of asset can be sold on the market for P. Yet the A bank is the most efficient user of its assets, i.e. they are bank specific. Moreover, the A bank's advantage may vary across assets. The relevant characteristic is captured by a variable θ uniformly distributed over the interval (0,1), whose cumulative distribution is $F(\theta) = \theta$. Assets with smaller values of θ are less redeployable to the market. If an asset with characteristic θ is sold on the market, then $p=p_B(\theta)$ with $p_H > p_B(\theta) > \rho/R$ and $dp_B(\theta)/d\theta > 0$. We assume that:

(4) $p_B(\theta) = \begin{cases} \varepsilon p_H \text{ if } \theta < \gamma \\ p_H \text{ if } \theta > \gamma \end{cases}$

More funds can be raised from assets sales than from borrowing, i.e.

(5) $p_B(\theta)R > p_H(R - R_B)$

We model the A bank's interaction with the market as a one-stage bargaining game. The A bank makes the market an offer with three components: a sale of measure α of the A bank's assets, a repayment $r \leq (1-\alpha)R$ from the A bank per unit of assets when $\tilde{R} = R$ and a transfer T to the A bank. This transfer corresponds to a price P per unit of asset sold and a loan L per unit of asset retained, i.e. $T = \alpha P + (1-\alpha)L$. If the market accepts the offer, it is implemented and bargaining is over. If it rejects the offer, bargaining breaks down and each part receives zero. As it is designed, the A bank pins down the market to its outside option. This corresponds to the case of perfect competition, i.e. the market makes zero profits.

The A bank's optimal offer maximizes its payoff subject to the market's meeting its outside option. The offer must satisfy three further properties. First, the incentive compatibility constraint, (2), otherwise the A bank will not monitor its remaining assets. Second, the market transfer to the A bank must be sufficient to refinance the A bank's remaining assets, otherwise these assets would be worthless and selling them would be more rewarding. Last, the A bank will sell its most redeployable assets (if any), i.e. all loans with θ above a threshold $\hat{\theta}$. Therefore, the A bank's problem is:

(6) $$max_{\hat{\theta},r,T}(1-l)\int_0^{\hat{\theta}}[p_H(R-r)-\rho]dF(\theta)+l+T$$

s.t. $r \leq (1-l)(R-R_B)$; $l+T+L_A^B \geq (1-l)\rho F(\hat{\theta})$;

and $$(1-l)\left[\int_0^{\hat{\theta}} p_H r dF(\theta)+\int_{\hat{\theta}}^1 [p_B(\theta)R-\rho]dF(\theta)\right]-T \geq 0$$

Under the optimal offer $(\theta_A^*, r_A^*, T_A^*)$, the A bank sells a fraction $\alpha_A^* = 1-F(\theta_A^*)$ of its assets.

Using the three constraints, the outcome is as follows.

a. If $(1-l)p_H(R-R_B)-(1-l)\rho+l+L_A^B \geq 0$, the outcome is efficient: The A bank funds all its assets borrowing from the market and does not sell any assets. Its payoff is:

(7) $$\pi_A = l+(1-l)(p_H R-\rho)$$

b. otherwise the outcome is inefficient: the A bank sells a fraction $\alpha_A^* = 1-F(\theta_A^*)$ of its assets to the market, with θ_A^* defined by:

(8) $$(1-l)\left[\int_0^{\hat{\theta}} p_H r dF(\theta)+\int_{\hat{\theta}}^1 [p_B(\theta)R-\rho]dF(\theta)\right]=(1-l)\rho F\left(\hat{\theta}\right)-l-L_A^B;$$

Using eq. (4), eq. (8) can be solved for the level of θ_A^*:

(9) $$\theta_A^* = \frac{l+L_A^B+(1-l)[(1-\gamma+\varepsilon\gamma)p_H R-\rho]}{(1-l)p_H[\varepsilon R-r]}$$.

And A bank profits are:

(10) $$l+(1-l)(Rp_H-\rho)-(1-l)R[p_H(1-\theta_A^*)-\varepsilon p_H(\gamma-\theta_A^*)-p_H(1-\gamma)];$$

<u>The B bank:</u>

At *t*=0 the B bank has a continuum of measure 1 of risky assets. At t = 3 its portfolio yields a random return $\tilde{R} \in (0, R)$. At t=2 it needs refinancing of ρ^B units of cash per unit of assets. The problem of the B bank is perfectly analogous to the one of the A bank but for one respect: in case of asset sales, the price it can get from the market depends on what happened to the A bargaining. If the A bank had to sell assets, B bank assets becomes less redeployable on the market. In particular, we assume that the parameter γ^B is increasing with the amount of assets sold by the A bank: $\gamma^B = \gamma + \frac{1}{2}\alpha(1-\theta_A^*)^2$, with $\alpha \in (0,1)$. The higher α is, the higher the contagion from the A's financial market.

From the solution of the bargaining game between the B bank and the market we get the profits for the B bank.

A1. If $p_H(R - R_B^B) - \rho^B + L_B^B \geq 0$, the outcome is efficient: The B bank funds all its assets borrowing from the market and does not sell any assets. Its payoff is:

(12) $\pi_B = p_H R - \rho^B$

B1. otherwise the outcome is inefficient and the B bank profits are:

(13) $\pi_B = p_H R - \rho^B - p_H R(1-\theta_B^*) + R[\varepsilon p_H(\gamma^B - \theta_B^*) + p_H(1-\gamma^B)]$

Where θ_B^* is equal to:

(14) $\theta_B^* = \frac{L_B^B + (1-\gamma^B + \varepsilon\gamma^B)p_H R - \rho^B}{p_H[\varepsilon R - r]}$.

<u>The B's Central Bank:</u>

We now turn to the B's central bank's problem. Its objective is to minimize B banks inefficiencies bearing the least cost. In particular we are interested in the intervention in the A market. The B's central bank minimizes B banks inefficiencies taking into account that intervening in the A market is costly (the parameter β represents the importance of this cost). The B's central bank chooses the level of A market intervention that satisfies the following equation:

(14) $L_A^{B*} = argmin\{p_H R(1-\theta_B^*) - R[\varepsilon p_H(\gamma^B - \theta_B^*) + p_H(1-\gamma^B)] + \beta L_A^B\}$

i.e.

(15)

$$L_A^{B*} = \left[1 - \frac{\beta(1-l)(\varepsilon R - r)}{R \propto (1-\varepsilon)\left[(1-\varepsilon)\frac{R}{[\varepsilon R - r]} + 1\right]}\right](1-l)p_H(\varepsilon R - r) - l - (1-l)[(1-\gamma+\varepsilon\gamma)p_H R - \rho]$$

From the first derivatives of eq. (15) we get that the Fed intervenes in the A market the higher is the contagion (α) and the lower is the cost of intervention (β).

As far as the liquidity of the A market is concerned, the Fed intervention depends on the level of A liquidity. Define the threshold level l^* as:

(16) $$l^* = 1 - \propto \frac{\Xi}{\beta} \frac{R(1-\varepsilon)\left[(1-\varepsilon)\frac{R}{[\varepsilon R - r]} + 1\right]}{p_H(\varepsilon R - r)^2}[p_H(\varepsilon R - r) + 1 - p_H R(1-\gamma+\varepsilon\gamma) + \rho]$$

The B's central bank intervention in the A market is increasing in A liquidity up to the level threshold level l^*, after that threshold it decreases. The threshold, however is a function of the degree of contagion: the higher the contagion and the lower the threshold. This means that in case of an extreme contagion the threshold can become negative, i.e. the maximum level of intervention happens when the A bank is illiquid.

The model illustrated above suggests that a national central bank can perform the functions of an ILOLR under two conditions:

i. the country whose central bank performs these functions must have a monetary and financial system that is more highly developed than the other country. This is the situation that empirically is found in the role that the United States plays in the world economy insofar as it has the largest financial market and in that it is the issuing country it has the dominant currency in international exchanges.[18]

ii. There is a high level of financial interdependence between the various economies. Indeed, the Fed granted swap lines to countries characterized by a high level of interdependence with the American financial system, in particular to central banks of many advanced economies.

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4. Were the swap lines provided by the Fed effective?

The granting of swap lines by the Fed and the effective cooperation between central banks reduced the banks' funding roll-over risk. This helped to reduce pressures on funding market in U.S. dollars and the risk of insolvency of some large banks, especially the major European banks.

Confirmation of this comes from different empirical papers. In Taylor and Williams (2009) and McAndrews *et al.* (2008), the effects of the dollar swaps are considered alongside those of the TAF. However, while the former conclude that the TAF auctions had no effect on the LIBOR-OIS spread, the latter show that both the TAF auctions and the swap lines led to a significant reduction of this spread. Baba and Packer (2009) consider the FX swap market, reaching the conclusion that the swap lines granted by the Fed and the dollar term funding auctions held by the ECB, BoE and SNB contributed significantly to reducing the FX swap deviations.[19]

It is, therefore, likely, that the Fed's swap line operations contributed to reducing the roll-over risk of banking systems heavily indebted in U.S. dollars. Furthermore, as shown by Achariya *et al.* (2011), high rollover risk translates into high default risk. Hence the need to consider the effects of the swap lines on the prices of five-year bank CDS relative to the countries that benefit from this form of support.

An empirical check was carried out on a sample of 42 banks in countries that made use of the Fed's swap lines. Table 3 shows for each extension of swap lines from the Fed the analysis of the variation in CD spreads between the average of five days prior to the date of the transaction and the average of time intervals following the operation: in particular the first five days following, the next five and a further five.

We take into consideration both the variation in bank CDS and the difference between these and the corresponding sovereign CDS. We show both the measure of absolute change and its significance level[20] and the percentage of banks that have registered, in the space of time considered, a negative variation of spread on CDS.

[19] Aizen and Pasricha (2009) consider four emerging countries, two of which benefited from the Fed swap lines. The empirical analysis shows that in the short term the swap lines led to a rise in the exchange rate of the swap countries over the non-swap countries. However, the repercussions of the swap lines on the CDS of the first countries compared to the latter are negligible.

[20] More precisely, if the change is significant to 99%

In general, there is confirmation of the fact that swap transactions have made it possible to contain the growth of the risk perceived by the market as to the strength of banking systems considered. The analysis shows that this containing effect was particularly significant in the first operation (carried out at the end of December 2007). This effectiveness decreased in the following operations and then increased again in mid-October 2008 when the Fed decided to provide U.S. dollar liquidity without any quantitative limit (Table 5).

Table 5 – CDS prices and Swaps operations (sample of 42 banks)

				Bank CDS			Bank-Sovereign CDS		
Date	level of Cds spread	N. of banks		Var 5 day pre and .. day after			Var 5 day pre and .. day after		
				5 day	10 day	15 day	5 day	10 day	15 day
12/12/2007	36.2	26	level	- 7.3	- 5.1	- 4.4	- 8.9	- 7.4	- 6.3
			sign	*	*	*	*	*	*
			% reduction	100.0%	92.3%	88.5%	100.0%	100.0%	95.8%
11/03/2008	125.8	31	level	28.3	3.8	- 14.5	26.2	3.3	- 12.8
			sign	*		*	*		*
			% reduction	0.0%	48.4%	87.1%	0.0%	44.8%	82.8%
02/05/2008	60.7	27	level	- 4.1	- 3.3	- 2.7	- 2.4	- 2.7	- 1.9
			sign	*	*	*	*	*	
			% reduction	96.3%	81.5%	70.4%	84.0%	68.0%	60.0%
30/07/2008	82.5	36	level	3.1	3.7	6.5	2.7	3.0	5.7
			sign	*	*	*	*	*	*
			% reduction	19.4%	22.2%	8.3%	23.5%	26.5%	14.7%
18/09/2008	159.9	35	level	4.5	23.1	6.0	5.0	15.4	- 13.9
			sign		*				
			% reduction	60.0%	25.7%	45.7%	60.6%	36.4%	57.6%
13/10/2008	114.5	32	level	- 29.7	- 9.4	- 12.9	- 28.6	- 27.7	- 33.1
			sign	*			*	*	*
			% reduction	81.3%	56.3%	62.5%	83.3%	90.0%	90.0%

Legend: * indicates 99% significance.

These results are confirmed when, instead of the level of bank CDS, we consider the differential between the prices of bank CDS and those of CDS on sovereign debt. Even the provision of swap lines in October 2008 led to a reduction in the differential between the prices of bank CDS and the CDS on sovereign debt over time, rather than limited to a short period, as happened in the case of the level of bank CD prices.

Further confirmation of the conclusions outlined above comes from an econometric estimate of the level of the spread between the prices of bank CDS and sovereign debt prices (BAEUR-STEUR) for the eurozone; in our model specification the dependent variable is explained through the spread

between the interbank rate of the eurozone and the OIS rate (EURIBOR-OIS) as an indicator of liquidity tensions, the quantities of U.S. dollars providing operations by the European Central Bank[21] (ECB U.S. $) and two dummy variables that relate to the post-Lehman period (Lehman) and the period after the Federal Reserve's commitment to provide unlimited dollar swap lines to the European central banks on 13th October 2008 (DUSWAPUNL).[22] As in Baba *et al.* (2009) we thought it useful to assess an exponential model GARCH (1.1) (EGARCH (1,1)) in the version proposed by Nelson (1991) because this model allows us to evaluate the effect of swaps on both the level of risk differential for banks and on its variability. Moreover, as is known, the Garch models are particularly used in the analysis of financial time series and for the analysis of the effects of monetary policy announcements on asset prices.[23]

Consequently the mean equation includes the previous variables, while the variance equation can be written as:

$$\ln(\sigma^2) = \alpha + \beta \left| \varepsilon_{t-1} / \sigma_{t-1} \right| + \mu \ln(\sigma^2_{t-1}) + \Upsilon(\varepsilon_{t-1} / \sigma_{t-1}) + \pi \ln(\text{US\$BCE})$$

where the first term on the right-hand side of the equation is the ARCH component, the second the GARCH component, while the third enables us to evaluate the asymmetry of the impacts of the shocks on volatility. The inclusion of provisions of dollars from the Central Bank in the equation of the variance permits us to assess whether the effect of these transactions, more than acting on the mean value of the CD prices of European banks also had an impact on their volatility. The estimate was carried out on daily data from the beginning of December 2007 to the end of January 2009: a sample of 305 days. The results are given in Table 6.

Table 6. Estimate of the spread between bank CDS and sovereign CDS (eurozone)

Variable	Coefficient	Z-stat	Prob
		Mean Equation	
C	0.760	61.15	0.00
EURIBOR-OIS	0.077	3.19	0.00
LEHMAN	0.695	66.89	0.00
ln(US$BCE)	-0.021	-7.27	0.00

[21] Source: Naohiko Baba and Frank Packer "From turmoil to crisis: Dislocations in the FX swap market before and after the failure of Lehman Brothers".

[22] Both this and the previous dummy is equal to 1 for the days following the event in question and 0 previous to it.

[23] See Beine *et al.* (2009) and Ehrmann and Fratzscher (2008), for example.

DUSWAPUNL	-0.957	-65.89	0.00
		Variance Equation	
C	-2.584	-7.29	0.00
ARCH	1.652	7.55	0.00
GARCH	0.726	12.78	0.00
ASSIMMETRY	-0.022	-0.18	0.85
ln(US$BCE)	-0.065	-1.69	0.09

Legend: Dependent Variable: BAEUR – STEUR. EGARCH(1,1) Model: method ML ARCH (Marquardt) – Generalized error distribution. Sample 12/03/2007 – 01/30/2009. Bollerslev-Wooldridge robust standard errors & covariance. Log likelihood: 259.59.

The results of the estimate confirm the indications found in Table 5. The ECB's provision of liquidity in dollars significantly reduced the prices of bank CDS, compared to those of similar sovereign bonds, both in relation to their size, and in relation to the effect of the Fed's announcement in the middle of October 2008 of its intention to supply U.S. dollars to major international central banks, including the ECB, without any limit. In particular, the latter effect can be evaluated in the order of one percentage point. The amounts of refunding in dollars appear to have reduced the volatility of the quotations relative to bank CDS, although the estimate of the relative coefficient in the variance equation is not sufficiently precise.[24]

The empirical evidence set forth above shows that the interventions by the Fed in the form of swap lines were successful. However, as we have seen, these interventions were limited to banking systems characterized by a high degree of interconnection with the U.S. banking system. This has meant that the dichotomy between economies highly integrated with the U.S. financial system and the peripheral economies has grown steadily wider. The latter, as they were unable to count on measures of support from the Fed in a crisis, were forced to pre-empt phases of financial instability by holding large amounts of foreign exchange reserves and introducing restrictions on banking activities. This negatively affected their competitiveness and hindered their integration into international financial markets. The gap between the financially developed and the less developed systems has the tendency to widen.

Conclusions

One of the main causes of the financial crisis of 2007-2008 was the significant increase in gross capital flows between countries that occurred between 2002 and 2007. This increase resulted primarily in a close interdependence between the European and U.S. financial system. In particular,

[24]However, the estimate of the relative coefficient in the variance equation is not sufficiently precise. The statistical significance of this coefficient would be higher if one assumed the errors to be normally distributed.

several European banks took out short-term dollar debts and bought long-term high-rated assets in U.S. dollars.

At the first onset of the crisis in September 2007, given the scarcity of liquidity on the U.S. money market, some banking systems, in particular of Europe, encountered significant difficulties in rolling over their short-term liabilities in U.S. dollars.

This led to a significant increase in the CDS prices of the banks concerned, in other words, in their risk of default. If this risk had materialized, this would inevitably have led to the contagion spreading to the U.S. banking system. This possibility was warded off by the intervention of the Fed, which, by allowing a large number of swap lines to central banks, solved the problem of dollar shortage that plagued banks with high maturity mismatches between assets and liabilities in U.S. dollars. As a result of these measures the prices of CDS on banks shorterly indebted in dollars fell immediately. However, the resolute intervention of the Fed was primarily motivated by the need to avoid the liquidity shortage of European banks leading to negative externalities on the US financial system. In a few words, the Fed exercised the functions of ILOLR, but only for its national interests.

The swap lines the Fed granted to the central banks of emerging countries were largely untapped. This is due both to the limited short-term debt in dollars of the banks in these countries and to the high amount of reserves in U.S. dollars held by those countries.

The behavior of the Fed shows a deep dichotomy in the world financial system. On the one hand, there are the financial systems of advanced economies and a few emerging countries, regarded as interconnected with the U.S. financial system, which can count on intervention by the Fed in the guise of a quasi-ILOLR.

On the other hand, there are the peripheral economies, with a low degree of interconnection with the U.S. financial system. These economies tend to protect themselves from the risk of currency and financial crises by holding large amounts of reserves and by imposing severe regulatory constraints on domestic banks. The high costs that such decisions entail for the peripheral economies inevitably penalize them by diminishing the competitiveness of their banking and financial systems.

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