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SHALL WE KEEP EARLY DIERS ALIVE?

Andrea Pinna

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CRENOS – CAGLIARI
VIA SAN GIORGIO 12, I-09100 CAGLIARI, ITALIA
TEL. +39-070-6756406; FAX +39-070- 6756402

CRENOS - SASSARI
VIA TORRE TONDA 34, I-07100 SASSARI, ITALIA
TEL. +39-079-213536; FAX +39-079-213002

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Via Is Mirrionis, 1
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Shall We Keep Early Diers Alive?

Andrea Pinna
Free University of Bozen-Bolzano
and CRENoS

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Abstract

Most extant explanations of financial crises emphasise the role played by negative shocks on the liability side of a bank's balance sheet. The vast literature on bank runs induced policy makers to build up a reputation as institutions willing to do anything to support the orderly fulfillment of depositors' and interbank claims. Nonetheless, the LTCM crisis of 1998 and the Subprime crisis of 2007 are compelling examples of how the banking industry is prone to systemic disruptions even without preference shocks or domino effect. This survey argues in favour of the still marginal literature on financial crises unfolding through the asset side of banks' balance sheets.

JEL Classification: G01, G32.
Keywords: Financial crises, Originate to distribute, Shadow banking, Diabolic loop.

1 Introduction

Taking the cue from the 2007-2009 Subprime crisis, this chapter proposes an overview of the literature on bank runs and financial contagion. Some pathbreaking models are examined to emphasise a slow but decisive shift of the literature, which started by addressing the issue of preferences shocks and is now focusing on the impact the access to collateralized borrowing has on the banking industry.

The following stylised facts are among those justifying the new approach:
- Banks increasingly invested outside their traditional loans activity, holding huge amounts of structured products that are continuously traded on financial markets and used to raise liquidity
- Banks transfer opaque structured products to other financial institutions in order to reduce the cost risky investments have in terms of reserves.
- A surge in the delinquency rate of a relatively small portion of loans in 2007 decreased worldwide liquidity.
- Public institutions struggled to sustain banks funding capacity through injections of liquidity.

Banks provide a valuable insurance to depositors who are uncertain about the time of their consumption needs. They do so by offering deposit contracts and using some of the proceeds to invest in illiquid assets. The necessity that the banking industry may perform such a valuable task without jeopardising the real economy justified an extensive research on the topic of financial stability. The modern literature on financial crises dates back to the early eighties and spread in a number of works the present paper does not attempt to consider thoroughly. The seminal work by Bryant (1980) and its formalisation by Diamond and Dybvig (1983), focused on models with one representative bank. These works emphasized the fragility of financial institutions facing a temporary gap between realizations of assets (long-term loans) and liabilities (short-term deposits). Early papers insisted on the weaknesses bank deposit contracts bring about. Allen and Gale (1988), Goldstein and Pauzner (2005), and Jacklin and Bhattacharya (1988) enriched the analysis linking depositors' expectations to the business-cycle. Adrian and Shin (2010), Allen and Gale (2000, 2004), Brusco

and Castiglionesi (2007), Cifuentes et al. (2005), Diamond and Rajan (2005), Freixas et al. (2000), Rochet and Vives (2004), although keeping much of their framework in the very same vein as previous models on bank runs, singled out what channels the run on one bank may trigger a financial crisis through. The latest developments in the modelling of financial crises are related to the ongoing Eurozone sovereign and banking crisis. Work by Acharya et al. (2011), Bolton and Jeanne (2011), Brunnermeier et al. (2011), Gennaioli et al. (2014), Gerlach et al. (2010), Mody and Sandri (2012), Panetta et al. (2011) and Popov and Van Horen (2013) addresses the interconnection among sovereigns and the banking sector, showing that it may channel both domestic and cross-border contagion.

I follow in Section 2 the traditional taxonomy of the literature on bank runs, emphasising differences among the "coordination failure" and the "business-cycle" interpretations of the phenomenon. In Section 3, models of contagion relying on the early withdrawal by some depositors are reviewed, and their adequacy in accounting for modern financial crises is disputed. Section 4 focuses on a more recent approach to contagion, whereby a crisis spreads through the asset side of bank balance sheet. Section 5 addresses the ongoing Eurozone sovereign and banking crisis. Section 6 concludes.

2 Bank Runs

The theoretical research on bank runs and financial crises is of particular importance because of its relevance for decisions of both regulators and investors. This induced a vast and diverse literature that evolved together with business models and financial innovation over the last 30 years. Its usual taxonomy is based on what kind of uncertainty triggers the insolvency of a financial institution. On the one hand, the sunspot approach assumes runs are caused by a shift in depositors' beliefs that is unrelated to the real economy. On the other hand, the business-cycle approach assumes that such a shift is due to shocks affecting economic variables.

In all models of bank runs, financial difficulties stem from the same friction: due to the illiquid nature of entrepreneurial projects, a bank is exposed to depositors' early claims over assets that cannot be easily

converted into cash. These depositors act as "early diers"and want to withdraw their deposits immediately. Whenever such maturity mismatch stretches withdrawals to a level the bank did not expect, the costly liquidation of long-term assets makes the value of a bank portfolio inadequate to meet liabilities. This induces even patient consumers to withdraw their money, as long as their bank has any value to pay out and before other fellow depositors seize it. Therefore, the mismatch between withdrawals and bank liquidity worsens.

2.1 Panic Runs

The sunspot view of bank runs suggests that withdrawals exceed their *ex ante* expected level because of self-fulfilling prophecies on exogenous events. In the three-period model of Diamond and Dybvig (1983), consumers are uncertain about the timing of their consumption needs. Banks are modelled as risk-sharing institutions that pool consumers' endowments at the initial date and invest them in a portfolio of long- and short-term assets. Since the focus of the model is on a bank liabilities rather than assets, the latter are simply risk-free investments paying a strictly positive return R if held over two periods. If the investment is liquidated after one period it pays no return, likewise the short-term storage technology. The bank offers depositors a contract allowing to receive either a fixed claim r_1 at date 1 or r_2 at date 2, in exchange for their endowment. Consumers are all identical ex ante, but each of them faces the privately observable risk of being an "early dier"who values immediate consumption only. Every consumer has the following state-dependent utility function:

$$U(c_1, c_2; \theta) = \begin{cases} u(c_1) & \text{if the consumer is an early dier in state } \theta; \\ \rho u(c_1 + c_2) & \text{otherwise.} \end{cases}$$

Where c_i denotes the level of consumption at date i, $1 \geq \rho > R^{-1}$ and $u(\cdot)$ is increasing, concave and satisfies the Inada conditions. In such a framework, the consumption path depositors choose may be mismatched with the timing of banks return on investments. There is free entry into the banking sector, thus banks maximise the expected utility of depositors in order to attract more customers. The way they do so is by providing agents with insurance against their idiosyncratic liquidity

risk. If the bank knows the number of early consumers, optimal risk-sharing is attainable. Under asymmetric information, however, any risk-sharing contract with $r_1 > 1$ allows early withdrawers to claim liquidity on illiquid assets at the interim date. Since the bank is exposed to short-term claims over long-term assets, there is a multiplicity of equilibria that allows the prophecy of a bank run to be self-fulfilling. The amount of consumption c_2 a depositor can get at date 2 depends in fact on how much a bank has to liquidate of its long-term investments, to satisfy early withdrawals at date 1. If some late depositors predict that more than the expected number of early diers withdraw their liquidity at the interim date, under a first-come first-served rule it is optimal for them to do the same. But then it is true that more than the ex ante expected number of early depositors take out their money at the interim date. It is therefore a best response for all late consumers to withdraw immediately, so that a run happens. Patient consumers would prefer to leave their liquidity with the bank if there were no unexpected withdrawals. However, they know there might be early withdrawals and their place in line matters to avoid facing the loss of their endowment. By contrast, no patient consumer attempts to withdraw his funds early if everybody believes no panic is about to occur. In such a case, bank assets satisfy both the liquidity needs of investors who are hit by the liquidity shock and those of patient depositors who wait for the payment of long-term investments.

When a bank run happens, some depositors who needed to satisfy an early liquidity need find themselves short of the cash they needed, whereas patient consumers have more cash than they need and cannot enjoy the higher return on long-term investments. Thus, consumers' welfare is not maximised. The focus of this thesis is on the microeconomic foundation of banking crises. However, it is natural that research on financial instability aims to derive run-preventing contracts and to perform welfare analysis. The results by Diamond and Dybvig (1983) are unsatisfactory in that respect. In fact, investment and deposit contract are chosen ex ante by banks that hope the good equilibrium will be achieved. Were the bank, or the regulator, able to anticipate a panic, they might take different decisions to avoid the run. Yet, the issue of what event causes depositors to run on their bank is not addressed, and banks simply turn out to be inherently unstable institu-

tions. Furthermore, when one widens the focus from a single bank to the financial system, it is necessary to find sunspots hitting all banks at once to justify a system-wide financial crisis.

Despite these shortcomings, the Diamond and Dybvig (1983) approach has been the most influential one to address the issue of financial instability. The vast majority of later work on the topic still borrows two main elements from such approach: (1) early diers determine unexpected demand for liquid assets, (2) patient consumers may misreport their type, to win the run on the bank and get their claims satisfied.

2.2 Fundamental Runs

Gorton (1988) conducts an empirical study to assess whether bank runs are systematically linked to the business-cycle, rather than being reactions to extrinsic uncertainty. Using the liabilities of failed nonfinancial businesses as the leading economic indicator, he finds that panics are systematic events that come at or near business cycle peaks.

In business-cycle models of bank runs, depositors react to new information. News are not specific to their own bank, but are deemed relevant in the assessment of its reliability. Thus, a run starts only if new information disputes the ability for a bank assets to meet its liabilities. When a shock endangers the solvency of a bank, depositors perceive the latter as riskier and may decide to withdraw their funds before other depositors claim the whole (insufficient) liquidity their bank is able to pay out early.

Jacklin and Bhattacharya (1988) modify the Diamond and Dybvig (1983) model and relate panics to the business-cycle. They emphasise the role depositors' information at an interim date can play in causing a bank run. The return on long-term investments is a random variable depositors receive interim information about. New information may induce patient consumers to mimic early diers who run the bank to claim their liquidity.

Allen and Gale (1988) model interim information similarly to Jacklin and Bhattacharya (1988). Their analysis is richer as they consider the opportunity for late consumers to access the same technology that is available to banks. On the one hand, the authors find out that bank runs can achieve optimal risk sharing between early and late con-

sumers. Such result arises if early liquidation does not affect the return on assets, and the liquidity is split among withdrawers on an equal basis rather than sequentially. On the other hand, if the asset is liquidated early at a loss and consumers cannot attain the same return on investment as their banks do, the fraction of late consumers who mimic early diers affects the total amount of available consumption and a run occurs.

2.3 Global Games

Models of bank run relying on coordination failures account for big effects following small shocks. Such a feature is typical of financial crises. Nevertheless, this work relies on extrinsic uncertainty and is of little help for policy makers. The business-cycle explanation accounts for the rationale underlying a run, but it rules out the possibility that a crisis is triggered by a small unexpected shock. The fact that a jump in the economy-wide performance is necessary to unleash a run makes the latter unlikely to happen.

The global games approach, developed by Carlsson and Van Damme (1993), combines the panic and the business-cycle views of bank runs. Such a technique links the probability of occurrence of a crisis to signals depositors get, at an interim date, about the future state of the world.

Frankel et al. (2003) show that the uniqueness of equilibrium for games with many players relies on the assumption of global strategic complementarities. Namely, agents' incentive to undertake an action increases monotonically with the number of other agents engaging in the same action. Under such assumption the technique provides testable predictions on whether real shocks are able to trigger a run, although the latter still stems from coordination failures.

Rochet and Vives (2004) introduce global strategic complementarities in a model where banks face the threat of a run by early diers *à la* Diamond and Dybvig. The authors assume investors cannot deposit their endowments in a bank without the intervention of intermediaries. The latter make the decision of withdrawing monotonic in the number of agents who take the same action, via a reputation effect linked to the acknowledgement of any wrong investment. An asset manager withdraws his investment only if the probability of failure of

the bank, conditioned to the signal and the behaviour he expects from the other managers, is sufficently high. This leads to the following equilibrium: if the signal about assets return is poor, bank failures are caused by insolvency; if the signal is good, failures caused by illiquidity may still occur only if many other managers are expected to withdraw.

Goldstein and Pauzner (2005) enrich the Diamond and Dybvig (1983) model, allowing the fundamentals of the economy to determine whether a bank run occurs. To obtain a unique equilibrium, they show that the uniqueness result adopted by Rochet and Vives (2004) can be generalised to a framework where strategic complementarities are one-sided. This means that the incentive to withdraw increases with the number of agents who do so, only as long as the latter are few enough to make the waiting strategy preferred to that of withdrawing. The authors focus on depositors' decisions rather than banks, allowing individuals to obtain noisy private signals on the fundamentals of the economy. The equilibrium result is unique and leads to a bank run only when the relevant economic indicators are lower than a threshold value. Runs are still triggered by bad expectations giving incentive to mimic early diers, like in panic models, but the fundamentals of the economy determine whether expectations are compatible with a bank run. This allows the authors to find a probability for *panic*-based run, and to relate such a measure to the performance of the economy as well as to the terms of the deposit agreement.

3 Domino Financial Crises

Hitherto revised models – based on either self-fulfilling prophecy, revelation of new information, or signalling problems – are focused on a single institution. These suggest what may start a crisis, but cannot account for contagion.

Bhattacharya and Gale (1987) introduce an interbank market in the Diamond and Dybvig (1983) model, to study the impact preference shocks have on the whole industry when banks are allowed to trade liquidity. In their model, a bank does not know the proportion of early diers among its depositors. With no aggregate uncertainty, the opportunity for trading liquidity at the interim date allows each institution to hedge against region-specific shocks. Such a market for liquidity

lowers the probability of a bank run, since illiquid banks can borrow from cash-awashed regions. Nevertheless, it introduces the possibility that a local shock affects the whole industry. The issue is typical of moral hazard: banks have an incentive to underinvest in costly liquidity and attempt to get it, only when it is necessary, from other peers of the interbank market. The presence of overlapping claims among banks can then produce a domino effect when the industry is hit by systemic shortages, with the bankruptcy of any institution dragging down all other peers of the network. A regulator cannot perfectly monitor banks' investment decision and, if a crisis occurs, the liquidity it may inject does not necessarily flow to institutions who need it.

After Bhattacharya and Gale (1987), many authors emphasised the role interbank markets play in propagating a crisis through overlapping claims. Allen and Gale (2000) study the impact the topology of an interbank market has on the risk of contagion. They consider a version of the Diamond-Dybvig model in a multi-region economy, wherein the proportion of early diers is random and negatively correlated across regions. In such a framework, the interbank market plays for banks the same role any bank plays for depositors in models of bank runs: it pools its users' resources to insure them against idiosyncratic shocks. In both cases, when there is no aggregate uncertainty, the first-best allocation of risk sharing can be achieved. However, if aggregate liquidity is scarce, interbank linkages provide a channel the shock affecting a bank can propagate through. Institutions that are hit by unexpected withdrawals at the interim date can avoid liquidating long-term investments, since imperfect correlation allow them to demand cash from banks in regions with liquidity in excess. When the phenomenon is reversed at the following date, claims of banks hit in different dates cancel out on average. If the shock is a systemic one, the only way a bank has to provide more consumption after claiming all interbank deposits is to liquidate the long-term asset. Thus, late consumers are induced to run on their bank. Allen and Gale (2000) show that the probability of contagion depends on the architecture of the interbank market: if every region is connected with the others, the initial impact of long-term assets liquidation may be attenuated and contagion avoided. On the contrary, if each region is connected with few others, the impact of the initial liquidation is strong in the closer regions.

Brusco and Castiglionesi (2007) investigate the same issue as Allen and Gale (2000) in a different multi-region economy. They account for moral hazard among regional banks and find a result that is diametrically opposite to that of Allen and Gale. Furthermore, in their model a financial crisis can precipitate even with no aggregate uncertainty. Consumers are the standard Diamond and Dybvig (1983) ones, with additional uncertainty on what region faces the higher proportion of early diers. The key assumptions that introduce moral hazard in the model are two: (1) differently from all models reviewed so far, financial institutions aim to maximise dividend payments rather than depositors' utility; (2) the investment technology allows banks to appropriate an unobservable part of the return and hide information on their long-term investments. Banks can choose among two different long-term investments: a safer asset and a riskier one, the latter yielding a negative *expected* rate of return. Investing in the riskier assets becomes attractive if banks, protected by limited liability, are undercapitalised and gamble with depositors' money. It turns out that depositors may find it optimal to choose a contract allowing their bank to engage in asset substitution, to enjoy a higher return from long-term assets. In fact, since the possibility that the riskier asset defaults is known at the final date, the liquidity coinsurance provided from an interbank market allows early diers to have their claims met, as long as the bank is able to borrow from other banks the liquidity it needs. At the final date, two outcomes may arise: if the bank who gambled is the one who lent money at the previous date, it goes bankrupt without affecting other banks; if the gambling bank was a borrower, its wrong bet trails lenders to default. Thus, although a network benefits depositors through liquidity coinsurance, such a benefit is potentially offset by their leniency and the cost of a greater exposure to systemic crises.

Freixas et al. (2000) model an interbank market that allows depositors to hedge against uncertainty on where they need to consume. Each regional bank is therefore uncertain about the amount of withdrawals it will deal with, and the interbank payment system insures against such a risk. However, if depositors in one region believe their destination will be liquidity-constrained, their best response is to behave as early diers at home and to carry the liquidity they need. This forces the local bank to liquidate its long assets early at a loss and, by

backward induction, the liquidation makes it optimal for depositors in other locations to withdraw all money they need for consumption in the first region. The interbank market may thus expose the industry to inefficient financial crises just because some depositors, who do not trust other financial institutions, trigger a run on their own bank.

Empirical research shows that interbank linkages are too weak to spread contagion as the theoretical literature suggests. Sheldon and Maurer (1998), Upper and Worms (2004), and Furfine (2003) estimate the matrix of bilateral exposure among banks in Switzerland, Germany and the US, respectively. They simulate the extent of contagion caused by the default of a single bank. Given their results, a domino effect does not explain the occurrence of the Subprime crisis.

4 Asset-Side Contagion

Models of domino contagion rely on banks' inability to meet their liabilities with depositors. Such approach reflects the importance banks have as insurance providers to their depositors, and the role played by an interbank market. Nevertheless, it accounts for passive financial institutions, who stand by and do nothing as the sequence of defaults unfold. Throughout the previous sections, asset prices were assumed to be unaffected by the crisis. Such a view does not consider the effect of market forces and mark-to-market accounting. The impact of price changes on the book value of banks' assets magnifies the adverse impact of counterparties' defaults.

Allen and Gale (2004), Diamond and Rajan (2005), and Cifuentes et al. (2005) show that the interaction among changes in asset prices and solvency requirements amplifies any initial shock. An immediate consequence of a bank default is that the liquidation of its long-term investments causes the deflation of their price, if the market is not perfectly liquid. Other banks may react to the reduction in the value of their marked-to-market balance sheet by selling their assets, to avoid breaching their commitments with depositors (deposit contract), money market funds (margin calls), and regulators (risk constraints). Sales induce a further decline in assets value, which may outweigh the effect of the initial reaction.

To account for such a phenomenon, one needs to single out a proper

source of friction in the financial market. Shleifer and Vishny (1992) describe fire sales – namely trades of an asset at prices below its fair value – when financial distress clusters through time in a generic industry where firms hold specialized assets. When a firm must sell its assets because of financial distress, potential buyers with the highest valuation are other firms in the same industry, who are likely to be in a similar financial situation and may therefore be unable to offer enough liquidity. The same account fits financial markets: because of asymmetric information or specialised investments strategies, outsiders are willing to pay for the asset less than its industry-specific value. According to Acharya et al. (2012) a bank with market power may even provide insufficient lending strategically, to make liquidity-constrained banks sell their industry-specific asset so that it can take advantage of lower asset prices.

Adrian and Shin (2010) show that marked-to-market leverage is strongly procyclical. The authors document that institutional investors, differently from households, respond to changes in the value of their portfolio by moving leverage in the same direction as the market. Thus, instotutional traders amplify the price trend by selling when prices slump and amplify the price trend. Allen and Gale (2004) build on Allen and Gale (2000) to show how such a behaviour allows small preference shocks to precipitate a crisis through self-reinforcing price changes. The key elements in the model are (1) the role liquidity plays in determining asset prices and (2) its interaction with three sources of intrinsic uncertainty, all resolved at the interim date: consumers have the usual random preferences *à la* Diamond and Dybvig (1983); the proportion of early diers in the economy is unknown; and each bank does not know the fraction of early diers it must deal with. Similarly to Allen and Gale (2000), banks facing higher than expected demand for liquidity at the interim date can smooth both their wealth and depositors' consumption over time by selling long-term assets to banks facing an unexpectedly low demand. The supply of liquidity in the short run is given by banks' portfolio decisions at the initial date. In an incomplete financial market, lenders cannot be remunerated contingent to the cost of providing liquidity in all states. Therefore, the price of long-term assets when liquidity is needed has to be sufficiently high to compensate the opportunity cost of holding liquidity when there

is no liquidity shock. Substantial sales determine cash-in-the-market pricing. As prices fall, any bank needs to sell an even larger proportion of its long-term assets. This can lower asset prices to an extent that prevents the institution from satisfying its commitments even when all long-term assets are liquidated. With the new lower asset prices, other banks need selling as well and put asset prices under further pressure. Thus, even small shocks can trigger a systemic crisis. Although the result is similar to that of Allen and Gale (2000), contagion occurs with no prespecified interbank linkage. The channel for contagion is provided by the spot market via a downward spiral in asset prices.

Diamond and Rajan (2005) analyse the same type of contagion as Allen and Gale (2004) in a general equilibrium model wherein the only assets in the economy, entrepreneurial loans, pay off at an uncertain date. If the number of assets that pay late is low enough, the banking industry has the available liquidity it needs to fulfill claims by early diers. Although the demand for liquidity at the interim date exceeds its ex-ante expected value, a bank can in fact raise liquidity by selling late-realization assets to entrepreneurs whose projects pay early. The latter hold some excesse liquidity after the repayment of their loans. Thus, banks manage to allocate efficiently what entrepeneurs produce at the interim date, and the market allows absorbing the initial shock. On the other hand, if too many projects are delayed, any bank whose realised assets are inadequate to fulfil early withdrawals sells late-realization assets on an illiquid market. If the value of such assets is insufficient to raise enough liquidity, the bank may increase the interest rate on deposits. This attracts depositors from other banks but does not solve the aggregate shortage. Furthermore, banks' asset value drops when interest rates increase. Before banks produce the desired amount of aggregate liquidity by restructuring late projects, the self-reinforcing fall in prices may start a chain of defaults.

Whereas all models analysed thus far relied on preferences shocks to account for a bank run, Cifuentes et al. (2005) refrain from characterising what kind of shock hits the economy. The authors focus on how solvency constraints create liquidity risk in a system of interconnected financial institutions, when the latter mark their assets to market. Their model extends the main intuition of Shleifer and Vishny (1992) to the banking industry, wherein a shock on assets value makes

a bank violate its solvency constraint. The endangered bank must sell part of its assets and that, since the demand for the asset is less than perfectly elastic, lowers prices. Solvency constraints may then dictate further disposals and lead the banking sector to collapse, without need for either preference shocks or late consumers mimicking early diers.

The LTCM crisis of 1998 is a compelling example of how far a crisis may spread from the balance sheet of a financial institution, without any preference shock. When the value of LTCM's capital fell from $7 billions to $0.6 billion one month after the Russian government restructured its debt, the Federal Reserve Bank of New York arranged for a group of private banks to purchase the endangered fund and liquidate its positions without fire sales. LTCM raised big concern because it held many large positions in illiquid assets, whose price drop would affect other institutions. Notwithstanding the awareness financial regulators have of the possibility for financial crises to occur from the mere asset side of the financial market, most extant explanations of financial crises emphasise the negative externalities on the liabilities side of the balance sheet: it is the run by depositors that precipitates the crisis.

4.1 Modelling the Subprime Crisis

By virtue of the policies suggested over three decades of research, central banks managed to relegate demand-driven bank crises to break out in text books more often than in newspapers. Such a phenomenon came back in 2007 in the UK, one century after the previous bank run in the British banking system, when customers queued to withdraw their deposits in Northern Rock. The Subprime crisis, able to set off such secular event, questioned our understanding of financial crises. It does not fit either the account given by models relying on self-fulfilling prophecies or those stemming from domino effects.

Early diers do not seem to have played a primary role in the crisis: to begin with, banks got in trouble before anything happened to liquidity demand, and they kept the bad news secret as long as they could.[1]

[1] Shin (2009) reports on the run to Northern Rock: "The Bank of England was informed [of Northern Rock's funding problems] on August 14th. From that time until the fateful announcement on September 14th that triggered the deposit run (i.e. for a full month), the Financial Service Authority and Bank of England sought to resolve

Furthermore, central banks have now succeeded in appearing ready to do anything for the sake of financial stability. Thus, a consumer panic, either driven by phrophecies, interim signals or asymmetric information, does not give a satisfactory explanation to the extent of the crisis.

In force of central banks attitude, the present work calls for a change of focus towards contagion mechanisms wherein depositors do not care about drops in banks' portfolio value. They are conscious that their central bank and public insurance on deposits will keep deposits safe. This approach allows to focus the analysis on the consequences market fluctuations and risk constraints have on banks solvency.

Diamond and Rajan (2011) show that the overhang of illiquid assets increases the future return of holding them in the eve of fire selling. Opaque Asset Backed Securities (ABSs) are likely to depreciate much, since only few specialized firms can evaluate them. Thus, the prospect of buying undervalued assets in the near future induces an endangered bank to hold them hoping they will appreciate before breaching its commitments.

Heider et al. (2009) model an interbank market where financial institutions lend money to each other in order to deal with the traditional issue of early diers. The authors introduce asymmetric information about counterparty risk among banks. The private information each bank has on its risky investment produces adverse selection. This can lead the unsecured interbank market to freeze, because lenders hoard liquidity and the cost of the latter becomes too high for potential borrowers.

Acharya et al. (2011) emphasise the role played by rollover and liquidation risk in the Subprime crisis. Similarly to the model developed in the next chapter, they allow banks to borrow liquidity through repo agreements in the money market. In a two-state model, the authors show that the pledgeable value of an asset in the bad scenario is lower than its fundamental value. The reason is that, when the frequency of rollover is high, it is unlikely that good news make the value of an asset jump to its good state level by the rollover date. Banks assets have a liquidation cost. Thus, in order to avoid bankruptcy, borrowing banks do not issue debt with a face value higher than their debt capacity in

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the crisis behind the scenes, possibly arranging a takeover by another UK bank."

the bad state. Even a small decrease in the fundamental value of the asset at a rollover date may thus cause a large fall in banks debt capacity. Such effect is stronger when rollover is frequent and liquidation costs are high. It can be so important that the market for secured borrowing freezes. To the best of my knowledge, the model by Acharya et al. (2011) is the only one on the Subprime crisis that does not focus neither on early diers nor on changes in lending margins.

Repo margins were undoubtedly an important channel for contagion, when lenders updated their estimate of counterparty risk. Brunnermeier and Pedersen (2009) stress the difference between market liquidity and funding liquidity. Whereas the former depends on traders' ability to raise funding liquidity, the latter depends on the terms of loans such as lending margins. The worsening of lending conditions may then interact with market liquidity and start a liquidity spiral. When funding liquidity becomes expensive, solvent institutions may default. Such illiquidity risk, addressed by Morris and Shin (2009), is at the root of the model of contagion in the next chapter.

5 Contagion in the ongoing Eurozone sovereign and banking crisis

At the time of writing, the US banking industry has put the Subprime crisis behind it. Nevertheless, banks and governments in Europe are still coping with its consequences. Although European banks are currently liquidity-subsidized through lending facilities by the European Central Bank (ECB), they have failed to recover lending to the private sector. Moreover, creditors have repeatedly penalized governments of peripheral countries such as Greece, Ireland, Italy, Portugal and Spain (GIIPS).

The US had the largest exposure to subprime mortgages and opaque derivatives. Thus, something specific to European financial markets shall explain why the crisis had such a long-lasting effect in the Eurozone. Work by Acharya et al. (2011), Bolton and Jeanne (2011), Brunnermeier et al. (2011), Gennaioli et al. (2014), Gerlach et al. (2010), Mody and Sandri (2012), Panetta et al. (2011) and Popov and Van Horen (2013) allowed understanding the implications, for a monetary union,

of a contagion channel that was already recognized in the recent Russian and Argentinian defaults of 1998 and 2001. Such mechanism is unrelated to preference shocks. Contagion is channelled through the interconnection among sovereigns and the banking industry.

The portfolio of investments held by European banks is heavily biased towards debt issued by European governments. Apart from a "home bias"in the spirit of French and Poterba (1991), regulatory provisions are the main driver of such distortion: Popov and Van Horen (2013) point out that, for regulatory purposes connected to the implementation of Basel II, the weight associated to government bonds issued in domestic currency is 0%. Such assets are also exempted from the limit on large exposures that applies to all other asset holdings.

The European Banking Authority reports that, at the end of 2013, Spanish and Italian banks held 89% of their governments' debt. Given the amount of sovereign bonds held by domestic banks, the cost of public deficit in the Eurozone depends on banks' ability to refinance sovereign debt. Nonetheless, European banks' access to financial markets during the crisis hinged on the support provided by the same governments they finance. The fact that banks enjoy a more or less implicit backstop from their home government and are at the same time providers of capital through their holding of sovereign bonds is akin to having cross-liabilities in the balance sheets of banks and their governments. Brunnermeier et al. (2011) defined such linkage between a country's public finances and its banking industry the âĂIJdiabolic loopâĂİ.

If a bank faces default its government is likely to bail it out, both for the sake of orderly financial markets and to secure its own access to global financial markets. Reinhart (2011) claims that the bailout of Bear Stearns in March 2008 induced financial markets to believe that the US government would use taxpayers' money to bail out endangered banks. Such belief induces moral hazard in the banking industry and is expected to generate excessive risk-taking by financial institutions in the future. In the aftermath of the Subprime crisis though, the bailout of Bear Stearns and subsequently that of Anglo Irish in January 2009 had also an immediate effect documented by Mody and Sandri (2012). The cost of saving the Irish bank was prohibitive, since financial integration allowed the financial sector of some European countries to

become huge relatively to the rest of the economy.[2] If a government bails out banks in such a condition, its ability to (i) repay its debt and to (ii) sustain other financial institutions in trouble is hampered. In both cases, the ultimate unintended consequence is that of spreading the trouble of one institution to other domestic and possibly foreign banks.

Reinhart and Rogoff (2009) provide evidence on the relationship between government debt crises and banking crises. Gennaioli et al. (2014) show that sovereign defaults lower financial activity in the defaulting country. It is not clear whether public defaults are the genuine origin of a crisis though, as they may actually be the consequence of weak banking industries. Nevertheless, bad signals on the sustainability of public debt in the GIIPS countries affected the value of their banking sector and that of other European banks that had a big exposure to those sovereigns.[3] Contagion from the instability of public finances to domestic banks was certainly the channel that affected the Greek banking industry.

What happened in the case of Ireland goes a step further and shows the loop mentioned by Brunnermeier et al. (2011). In the Irish case, public finances were deemed safe as long as domestic banks were solvent. However, once the fiscal cost of banks' bailout appeared unsustainable for the Irish economy, the same phenomenon that happened in Greece caused a feedback effect of the deterioration of public finances on Irish banks.

In this section I revise the recent literature that focuses on such case: the difficulty of one or more banks affects sovereign risk and that, given the exposure of European banks to their governments via bond holding and implicit/explicit guarantees, affect both the domestic and the foreign banking industry.

[2]The outstanding debt of the three main Irish banks in 2008 was bigger than the country's GDP.

[3]Gennaioli et al. (2014) claims that âĂIJthese events played a key role in the decision to refinance the European Financial Stability Fund (EFSF): averting sovereign defaults was seen as a key prerequisite to avoid widespread banking crises.âĂİ

5.1 The “diabolic loop"

Gennaioli et al. (2014) show that sovereign bonds holding by domestic banks lowers the cost of public debt. Foreign financers are less concerned with a sovereign default since it would dry up domestic liquidity and then investment, output, and tax revenue in the economy. In their model, contagion goes from the government to banks who hold public bonds. However, the connection between banks and sovereigns is two-way. On the one hand, banks enjoy the explicit and implicit backstops offered by their home government. On the other hand, sovereigns have a strong ally in a banking industry that provides funding both to the government and to entrepreneurial projects that result in tax revenues.

Given the size of sovereign bonds holding relatively to banks' total assets in Europe, and in force of banks' eligibility to borrow either through discount window facilities at the ECB or via repurchase agreements, the risk of sovereigns' default lowers banks' ability to gather liquidity. As of February 2014, government debt accounted for 5.8% of banks' assets in the Eurozone.[4] At the same time, the lack of funds prevents governments from putting in place bailout schemes for troubled banks, as well as stimulus packages for the rest of the economy.

Acharya et al. (2011) show that bailouts of the financial sector ultimately caused the rise of sovereign credit risk in Europe, and that sovereign credit risk increased the credit risk of financial institutions. Abstracting from the possibility of banks' debt restructuring, the authors show that a government may have an incentive to transfer wealth from the productive economy to banks. The decrease in banks' debt costs a government the issuance of additional sovereign bonds. That dilutes the value of outstanding debt, whereas the higher future taxation lowers expectations on economic growth and tax revenue. In such framework, a bailout initially stabilizes endangered banks. However, if the adverse effect on the value of sovereign bonds is big enough, the value of banks' assets and that of the implicit guarantee from the government fall. As this happens, the two risks move together. Such theoretical result is confirmed by the empirical findings in Mody and Sandri (2012), who find that the cost of financing for European countries ap-

[4]The same figure to a country-level is 10.2% for Italy, 9.5% in the case of Spain, and 7.4% for Portugal, according to data from the ECB.

peared tied to the outlook of its banking industry since the bailout of Bear Stearns.

Mody and Sandri (2012) look at monthly data to show that since mid-July 2007 the change in spreads of sovereign bonds – which Pagano and Von Thadden (2004) had shown to be white noise – was related to the risk of the financial sector (proxied by CDS spread of US banks). After Bear Stearns, a linkage emerged between national banking industries in the Eurozone and the spread of the relative governments over the German cost of public debt. The authors show that changes in the prospect of banks' value began to have an impact on sovereign spreads, after the bailout of the US bank, with a lag of two-three weeks. The nationalization of Anglo Irish in January 2009 reinforced the market expectation that governments would bear high fiscal costs to sustain endangered banks. At the same time, it was clear that such costs were not affordable. The correlation between banks' value and sovereign spreads became contemporaneous.

Similarly to the case of domino models, instability of banks and sovereigns reinforce each other in the presence of cross-liabilities. Thus, rather than providing a shelter, the connection between public and private institutions worsens the crisis. The findings by Mody and Sandri (2012) confirm that the contagion channel works in both directions: sovereign spreads mirror the domestic vulnerabilities of national banking sectors, and this feedback loop has more a severe impact on countries with high debt-to-GDP ratios. Gerlach et al. (2010) find the specular result that sovereign spread increase with the size of the banking industry in a crisis, particularly in the presence of government rescue packages.

Panetta et al. (2011) measure the impact of public finances on the risk associated to banks of all troubled Eurozone countries. They find that on average, in 2010, 30% of the spread was explained by sovereign risk. In the case of the GIIPS countries, such percentage reaches 50%. The authors performed the same assessment on pre-crisis data and find that sovereign risk had a negligible impact on borrowing costs of banks in 2006, whereas bank-specific factors explain most of the spread.

5.2 Cross-border contagion

The fact that banks in the Eurozone hold sovereign bonds issued by different European countries is good for diversification purposes ex-ante, but it creates scope for cross-border contagion in the case of default.

Panetta et al. (2011) report that banks from countries with strong public finances but with sizeable exposures to sovereigns or banks headquartered in the PIIGS countries were affected by the instability of the latter, leading the expected default frequencies of French, German and Italian banks in particular to move together in 2010-2011.

Popov and Van Horen (2013) investigate whether the banking sector may spread financial distress from defaulting sovereigns to other countries. When banks of European countries in a good financial condition face the deterioration of their exposure to endangered sovereigns, that affects negatively the lender country via lower lending to its government and private sector. The authors provide evidence that lending by European banks in non-endangered countries recovered slowly after the Subprime crisis when their exposure to endangered countries was above the median level. Bolton and Jeanne (2011) show that endangered sovereigns in the Eurozone issue too much debt in equilibrium, whereas countries in good financial conditions do the opposite. In lack of fiscal integration, virtuous governments supply little debt in order to exploit their monopoly power in case of a flight to quality. On the contrary, governments with weaker public finances issue too much debt because they do not consider the externality cost faced by other countries if a crisis materializes. Such inefficient supply of "safety" as a public good arises regardless of moral hazard created by the possibility of bailouts.

6 Concluding remarks

Since the first formalization of bank runs was developed in the early eighties, the literature on financial crises helped policy makers to understand the sources of instability in the banking industry. The focus was first on the difficulty. for a single bank, to solve the maturity mismatch between assets and liabilities when depositors faced preference shocks. The evidence that runs were related to banks fundamentals

switched scholars' attention towards the problem of signalling. At the industry level, the development of interbank markets allowed banks to cope with idiosyncratic shocks. Nevertheless, it paved the way to contagion. The latter was first addressed as a domino effect among banks balance sheets, and then as the result of sudden sales of marked-to-market collateral. The policy implications of such developments allowed western governments and financial institutions to lower the frequency of crises occurrence.

Yet, the Subprime crisis questioned our understanding of the forces able to cause distress in the banking industry. There was no run on any bank in the former stages of the turmoil, and the latter is not explained by the extent of banks interconnectedness. A still unformed strand of the literature has brought its attention away from the issue of early diers, and is focusing on funding conditions in the interbank market when liquidity needs stem from the performance of banks' investment rather than from depositors' preferences.

The Subprime crisis began with the discovery that highly structured financial derivatives were overpriced.[5] Overly exposed banks lacked the opportunity to raise from interbank markets the liquidity they needed to fulfil their extant commitments. The tightening of repo margin and the hoarding of liquidity by some institutions have been proposed as possible explanations. In the next chapter, I develop a model of contagion that takes no account of early diers and focuses on asset opaqueness, roll-over frequency, and risk constraints to contribute explaining contagion in the crisis of 2007-2009.

[5]The paternity of this mistake is not addressed in this thesis, although the moral hazard problem with rating agencies and the lack of time series on new custom-made products seem good explanations.

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