1. Central Banks and the Financial System

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Introduction

This chapter reviews the factors that make a financial system fragile and discusses the interaction between financial fragility and monetary policy. We argue that financial fragility is a deeper phenomenon than that which manifests itself when the price of some financial assets appear to follow a bubble. The fundamental fragility of a financial market does not arise from irrational behavior (although such irrationality seems to be routinely observed in financial markets).

The fundamental fragility of a financial system arises from its role in liquidity transformation. We shall illustrate a few examples of liquidity transformation, and the nature of the market fragility associated with it. As it will be apparent from the different examples, liquidity transformation is a central and ever-present function of financial markets. And therefore the 'fragility' of financial markets is an unavoidable fact of life. The challenge for policymakers, including central banks, is how to minimize the occurrence of financial crises which arise from a breakdown of liquidity transformation, and how to design their policy taking into account the possibility that such crises might occur.

We argue that a crucial variable in the Taylor rule, the tool most central banks use, albeit in quite different forms, to set the level of interest rates, is the real rate of interest the rule targets. Central banks

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typically treat the real rate as a constant, failing to recognize that the ex-ante real rate should be set so as to correct the inefficiency which arises by the incentive of financial intermediaries to borrow too much and borrow too short. This risks leading the economy into a low interest rate trap. Low interest rates induce too much risk taking and increase the probability of crises. These crises, in turn, require low interest rates to maintain the financial system alive. Raising rates becomes extremely difficult in a severely weakened financial system, so monetary authorities remain stuck in a low interest rates equilibrium. Following this introduction the paper is organized in four sections. We start by taking some distance and asking why were central banks created and to what extent and for what reasons do modern central banks differ from their precursors at the turn of the 20th century. We then ask to what extent has the crisis influenced the thinking of central bankers. After these introductory comments, we come to the core of the chapter: Why are financial systems fragile? We conclude by discussing possible remedies.

The Functions of Central Banks

There have been a number of comments regarding the role of central banks in the 2007–2008 crisis. While we think we can characterize the economics profession as largely unanimous on the broad appropriateness of central banks' interventionism and interventions as the crisis unfolded, within the larger business and financial community there have been a number of critics. Much less uniform views, even among economists, can be found on the question of whether central banks could have prevented the crisis or, worse, whether central banks caused the crisis through policies that provided the support to a credit bubble, especially in the United States.

The business of central banking has evolved tremendously in recent decades. Among the most notable evolutions we list the diffusion of legally-sanctioned forms of central bank independence, the spreading of inflation targeting as a guide to monetary policy and the establishment of the European Central Bank managing a currency for a group of 16 countries. A common conceptual thread in these reforms has been the view that the effectiveness of central banks could only be enhanced by limiting their mandate and allowing them to pursue such a mandate free from external influences. Until the 2007–2008 crisis, such reforms have been regarded as highly successful, bringing about a period of low and stable inflation and sustained growth in the 1990s.[2]

The direction of central banking in recent decades, focusing on the management of inflationary expectations with the ultimate task of price stability, contrasts with the experience of the early years of central banking in the two countries where substantial financial activities had developed: England and the United States.

The Bank of England was created to arrange finances for the government: it was supposed to be the government debt manager. Yet, after a succession of financial crises in the 19th century, it transformed into the guardian of the financial stability of the City of London, adopting a modus operandi in line with Walter Bagehot's (1873) influential suggestions.

The case of the US Federal Reserve is paradigmatic.[3] The US National Monetary Commission, chaired by Senator Nelson Aldrich, was set up in 1910 to investigate the workings of foreign financial systems and central banks, to find out whether setting up a US central bank would help prevent the liquidity crises, followed by widespread financial crises, that characterized the US financial system during the National Banking Period (from 1863 to 1913). During this period, two notable attempts to set up entities performing the functions of a central bank were the evolution of the Independent Treasury, which during the tenure of Leslie Shaw (between 1902 and 1907, on the eve of the last and arguably most serious crisis of the National Banking Period) actively injected and withdrew funds into the money market with the explicit objective of stabilizing it, and the clearinghouse associations, such as the New York Clearinghouse Association (1854), which by netting payments reduced the circulation of specie thus attempting to reduce the risk of liquidity shortages due to failures in the payments system.

Sprague (1910) was the best known advocate of a creation of a US central bank. Writing on the 1907 crisis he concludes (p. 320):

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[2] With the notable exception of the experience in Japan.
[3] See Miron (1989).

> Somewhere in the banking system of a country there should be a reserve of lending power, and it should be found in its central money market. Ability in New York to increase loans and to meet the demands of depositors for money would have allayed every panic since the establishment of the national banking system. Provision for such reserve power may doubtless be made in a number of different ways. This investigation will have served its purpose if in showing the causes and consequences of its absence in the past it brings home to the reader the need not only of this reserve power, but also of the readiness to use it in future emergencies.

A stable financial system is a necessary condition for a central bank to carry out a macroeconomic mandate (this is the argument often cited by the European Central Bank) such as inflation targeting: a corollary of this statement is that the central bank should be the guardian of financial stability. Conversely it has also been argued that macroeconomic stability, to which the central bank can contribute with its actions, is a prerequisite for financial stability. Indeed, many have suggested that one of the prime causes of the 2007–2008 crisis was the buildup of global imbalances in savings and investment across different macro regions. The arguments cited above are consistent with the following proposition: *the central bank should pursue its macroeconomic mandate with all means at its own disposal, including interventions in the money markets; the concern for financial stability does not imply deviations of interest rates from the path dictated by the objectives of macroeconomic stability (i.e., price stability).* What this proposition more specifically implies, is that the path of interest rates which results from a maximization problem that does not take into account the potential and determinants of financial crises is equal to one that solves out financial markets and their instabilities into the maximization problem. Moreover, the pursuit of an inflation target does not preclude the ability of the central bank to take action in the event of a crisis and use a wide and changing array of tools to avoid a chain of liquidations among financial intermediaries, with severe impacts on economic activity.

In this chapter we want to challenge the proposition in the paragraph above, hoping to contribute to a discussion on the development of central banking in the years to come. As the evolution of the financial systems of New York and London shaped the way for the development of the US Federal Reserve and the Bank of England in the early 20th century, so the development of financial markets throughout the globe witnessed in the past two decades will have to induce an equally important evolution of the structure and operations of central banks.

Lessons From the Crisis

When discussing central banks' roles in financial markets it is essential to distinguish ex-ante and ex-post. Ex-post, once a financial crisis has materialized, few disagree with the need for the central bank to intervene employing all the tools at its disposal. The typical telltale of a financial crisis is a spike in the demand for liquidity (more on this in the following sections). Since Bagehot (1873), the recipes for responding to financial crises have been routinely applied by central banks: abundant liquidity supply through low interest rates and open market operations; access to the discount window; and, as we have seen in recent months, a much enlarged universe of collateral instruments to obtain credit from the central bank (that is to obtain loans in central bank money), as well as access to central bank credit by a wider variety of financial intermediaries. Because the central bank is the monopolist supplier of the safest means of payment, i.e. central bank money, it is only to be expected that it will play an active role during times of financial stress. The lessons of Bagehot and Sprague have been well absorbed.

Matters, however, are very different ex-ante. Thinking of what central banks should do ex-ante, that is when financial markets work smoothly, economists have mostly focused on the question whether central banks should worry about the buildup of 'bubbles' in financial asset prices, under the implicit assumption that a financial crisis is the bursting of a financial bubble. Below, we shall review arguments in favor of and against central banks' intervention in the buildup of financial markets bubbles. These arguments, however, can and should be extended to the more general case and the more general question of whether and how central banks should take into account, in their day-to-day operations in normal times, the possibility of financial instabilities.

The argument that monetary policy should not be influenced by the concern for the fragility of financial markets is a prominent and well argued one among academics and policy-makers. A common view (see for example, Bernanke and Gertler, 1999) is that financial stability and price stability are 'highly complementary and mutually consistent objectives' which can be jointly pursued through a flexible inflation targeting regime, whereby central banks adjust monetary policy actively and pre-emptively to offset incipient inflationary or deflationary pressures. This prescription derives from a model of monetary transmission (see, for example, Bernanke, Gertler and Gilchrist, 1999) which allows for financial intermediation by assuming that policy interest rates induce changes in the external finance premium, the difference in cost between external funds and retained earnings, which is a characteristic of credit markets with asymmetric information. The channel through which interest rates affect the external finance premium are balance sheets and bank lending. The basic conclusion is that the richer and more realistic description of the monetary transmission mechanism to include financial intermediaries and balance sheet effects makes monetary policy more potent than simpler models would lead us to believe. In these models the complementarity between macroeconomic stability and financial stability arises essentially because the procyclicality of policy interest rates, rising during inflationary periods and declining in deflationary periods, dampens asset price fluctuations, as asset price booms tend to go together with inflationary pressures and, vice versa, busts with deflationary conditions.[4] For these reasons, Bernanke and his co-authors argue that central banks should not worry about the possible buildup of 'bubbles' in financial markets, and even less about pricking them. They should simply be aware of the effects on aggregate spending of presumed bubbles or of other fluctuations in asset prices, and be prepared to respond in the case of sudden changes in the price of financial assets. Recently Fed chairman Ben Bernanke (2010) has reiterated the argument in a discussion of monetary policy in the United States around the boom and bust of the housing market. He illustrates the output of a vector autoregression (VAR) of seven

[4] The experience of the years leading up to the recent crisis, years characterized by low and stable inflation and asset price booms, naturally puts into question this view.

variables, including measures of economic growth, inflation, unemployment, residential investment, house prices, and the federal funds rate, estimated using data from 1977 to 2002. He then uses the estimated model to simulate the federal funds rate in the intervening years as well as the behavior of house prices. The exercise shows that the actual federal funds rate moved broadly in line with the predictions of the model, while housing prices were widely outside the model's predictions. His conclusion is that house prices movements from 2002 to 2009 are hardly connected to either monetary policy or the broader macroeconomic environment. This lack of a systematic relation between the dynamics of asset prices and monetary policy leads Bernanke to conclude that it would be inefficient for monetary policy to deal actively with asset prices, before potential disruptions manifest themselves. The absence of a systematic relation between the evolution of asset prices and monetary policy instruments (together with other relevant macroeconomic variables) is consistent with the hypothesis that monetary policy instruments may not have an effect on financial asset prices in a robust and reliable way.[5] In particular, Bernanke claims it is impossible to detect asset 'bubbles' before they burst and therefore central banks should not engage in the activity of detecting bubbles and pricking them. At the same time, however, he recognizes that the damage produced by the rapid deleveraging caused by precipitous asset deflations justifies that central banks 'must be especially vigilant in ensuring that the recent experiences are not repeated'. This remark is in line with Greenspan (2003) who describes a kind of risk management approach to monetary policy: 'Recognizing that monetary policy decisions have to be taken in conditions of uncertainty, and that certain low-probability events may have large negative consequences on the economy, monetary policymakers may take actions that are difficult to justify in terms of the observable state of the economy, but find an explanation as hedges against tail events'.

These statements represent a significant departure from the view that central banks should not worry about the possible buildup of 'bubbles' in financial markets, and much less about pricking them,

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[5] The notable exception here is the linear-quadratic optimal control result that the instrument has no detectable correlation with the equilibrium realizations of the target variable when at an optimum: the only fluctuations of the target variable are due to uncontrollable idiosyncratic disturbances.

and that they should simply be aware of the effects of presumed bubbles or other fluctuations in asset prices on aggregate spending. Yet, both Bernanke and his predecessor at the Federal Reserve do not offer specific guidance as to the role of monetary authorities vis-à-vis financial markets in 'normal' times: this is what we are going to discuss in the next section.

The Fragility of Financial Markets

Many commentaries on financial markets identify their 'fragility' with the phenomenon of bubbles: sustained and often sudden increases in the prices of certain financial assets that make them attractive to investors, whose investments further drive up prices, well beyond what is justified by the expected returns from those assets. Bubbles 'burst' when investors realize their enthusiasm is unjustified. This is clearly an important phenomenon in financial markets, one that will always be present because information about the value of assets is always incomplete, and therefore investors think that other investors are, through their behavior, revealing incremental information about the value of assets.

However, the fundamental fragility of financial markets does not require investors to behave in a way that ultimately proves irrational (although such irrationality seems to be routinely observed in financial markets): it is associated with liquidity transformation. Through liquidity transformation different agents, with different transactional needs, can be pooled together to provide long-term funding for productive investments. The pooling of diverse transactional needs permits, in principle, the stability of long-term funding. Liquidity transformation is a socially productive activity because it is generally the case that production possibilities become more attractive whenever investment horizons can be lengthened.

Liquidity transformation is produced by different intermediation technologies. The two simplest technologies for producing liquidity transformation are a bank and a securities market. Consider a bank. First: it issues short-term debt, in the form of short-term deposits or checking accounts, and with them it finances long-term loans. As long as the liquidity needs of depositors and checking account holders are sufficiently diversified, the bank is viable and profitable. However, were the bank compelled to provide funds to a large fraction of its depositors or account holders simultaneously, the value of its investments would likely fall short of the value of its short-term debt. A securities market is very similar. Through it, an issuer can raise, in principle, long-term funding. Trading activity in the (secondary) market allows investors with diverse liquidity needs to enter and exit the market flexibly. If the securities market did not exist many fewer investors would be willing or able to commit funds for maturities matching those needed by the issuers. The secondary market would break down if the smooth mechanism that brings together buyers and sellers stopped working. What would make a bank or a securities market experience a crisis? What is sufficient is the fear of not recouping the value of one's investment. This can happen any time to the bank clients, if they fear that all may want to withdraw their cash at the same time (because all know that there is not enough value to satisfy every depositor). But this can also happen in securities markets: investors will be unwilling to buy securities if for any reason they suspect not being able to sell them when they need to. Such market breakdowns are market failures, i.e. spontaneous market equilibria that generate inferior welfare levels. When markets break down, funding for long-term projects dries up and society is forced to less efficient productions, implying lower income for everybody. In this section of the paper we shall illustrate a few examples of the market fragility associated with liquidity transformation. As it will be apparent from the different examples, liquidity transformation is a central and ever-present function of financial markets. And therefore the 'fragility' of financial markets is an unavoidable fact of life. The challenge for policymakers, including central banks, is how to minimize the occurrence of financial crises which arise from a breakdown of liquidity transformation, and how to design their policy taking into account the possibility that such crises might occur.

The first example (which elaborates on Hölmstrom and Tirole, 2011) illustrates one aspect of the fragility induced by liquidity transformation. It shows that an amount of 'inside' liquidity, i.e., liquidity created by financial intermediaries, that is sufficient in the aggregate may not be enough to make sure that every actor in the marketplace has access to a sufficient amount of liquidity when she needs it. In such a situation 'outside liquidity', i.e., liquidity created by the monetary authorities may be needed even in the absence of macroeconomic shocks.

The second example also borrows the analytical framework developed in Hölmstrom and Tirole (2011) to show how financial intermediaries may be subject to 'runs' and face spikes in liquidity demand in a way that is similar to the 'runs on banks' studied in the time-honored Diamond-Dybvig model. These examples illustrate two different aspects of the market fragility associated with liquidity transformation and show how central banks can intervene to accommodate spikes in the demand for liquidity. In the following paragraph we shall move one step further, showing that inappropriate monetary policy can induce excessive liquidity transformation and, through this channel, raise the probability of a crisis. In this context we shall show that the ex-ante 'optimal' monetary policy differs from the policy that is optimal ex-post, that is after a crisis has developed, as the two need to move in opposite directions: relatively higher interest rates ex-ante to reduce the incentive to engage in excessive liquidity transformation and, to the extent that sudden needs for liquidity still arise, relatively accommodative monetary policy ex-post to limit the damage to the real economy.

Liquidity transformation and financial fragility

The first two examples illustrate the fragility associated with liquidity transformation. We take the amount of liquidity transformation as given and discuss why it makes financial markets fragile. In the third example we shall discuss why monetary policy may induce 'excessive' liquidity transformation, thus contributing to making markets more fragile.

Dispatching inside liquidity

A well functioning financial market should be able to produce enough 'inside liquidity' to meet the liquidity shocks it needs to withstand. The ability to do this hinges on an efficient dispatching of available liquidity toward those intermediaries in need of cash. This can be accomplished by pooling the available liquidity at the level of financial intermediaries, who then re-dispatch it through a mechanism that Hölmstrom and Tirole (2011) describe as akin to drawing from credit lines. This is clearly a superior arrangement compared to a situation in which each intermediary hoards liquidity to withstand a possible shock: hoarding results in a waste and therefore a potential shortage of liquidity, as intermediaries that end up awash with cash do not lend it to those with a shortage of liquidity. What can cause this efficient distribution of inside liquidity to break down? The most relevant case are macroeconomic shocks, when inside liquidity is insufficient because all intermediaries face the same need for liquidity and all at the same time. In the presence of macroeconomic shocks (as illustrated in Hölmstrom and Tirole 1998) even if intermediaries were to diversify holding the stock market index (i.e. claims on the aggregate economy) they could not create a store of value that can be resold in case of liquidity needs that hit the entire economy. But the efficient distribution of inside liquidity can break down also in the absence of macro shocks: this can happen if, for some reason, financial intermediaries are unable or unwilling to redistribute efficiently an otherwise sufficient level of inside liquidity. We shall illustrate this point elaborating on an example described in Hölmstrom and Tirole (2011). There are three periods and the real interest rate between each period is zero. In $t = 0$, an entrepreneur finances a project whose initial cost is I; borrowing B from investors and contributing E in equity, so that $B + E = I$. The project does not generate any revenue at $t = 1$; actually with probability $1/2$ an overrun (a 'liquidity shock') of L arises, that must be covered if the project is to go on and produce income at $t = 2$, otherwise the project is liquidated and yields no income. With probability $1/2$, there is no overrun and therefore no extra expense at $t = 1$. At $t = 2$, revenue accrues (provided that the overrun, if it happened, has been covered). The total proceeds are then shared between investors and the entrepreneur. The share that goes to the entrepreneur (in case of a success) must be large enough to make sure that he puts enough 'effort' into running the project. To compute the pledgeable income, that is the maximum amount that the entrepreneur can credibly promise to investors, note that, as of $t = 0$, the expected contribution of investors to this project is $B+1=2L$: this is the minimum that must be promised to bring them in at date 0. In fact, under perfect competition it is all that is needed to bring them in. Thus the pledgeable income at $t = 0$ is:

$$P = B + 1/2\, L \tag{1.1}$$

All that remains goes to the entrepreneur. (In computing P this way we are assuming that the return on the project, which we have not specified, is large enough for the entrepreneur to have an incentive to put in enough effort). Thus, if investors are promised P as of $t = 0$, the project will be financed even if investors know that it might need refinancing and, in case of success, a large enough share of the revenue will have to be turned over to the entrepreneur. However, what looks feasible as of $t = 0$ may no longer be feasible at $t = 1$. Assume an overrun occurs in $t = 1$. The entrepreneur could look for new investors who are willing to refinance his project, but it is not clear he would find them. The reason is that all he can promise is P in $t = 2$; but to keep the project going he needs L. If $L > P$ (that is if $L > 2B$) he will find no investors and the project will be abandoned. (Note that offering the new investors, those that come in $t = 1$, seniority with respect to the investors that came in the period before does not help. If $L > P$ the project is abandoned even if the entrepreneur were to give 0 to the original investors and P to the new ones). There are two ways an entrepreneur can insure against such liquidity shocks. The inefficient way is to hoard liquidity in case an overrun occurs. This is inefficient because capital would remain idle. Hölmstrom and Tirole (2011) suggest that the entrepreneur could instead negotiate a credit line with a bank. For a fee F paid in $t = 0$, the bank could commit to pay L in $t = 1$. If the overrun occurs and the credit line is drawn, the bank becomes the senior creditor (the original creditors get nothing) and therefore receives P in $t = 2$. The commitment fee is:

$$F = (1/2)\ (L - P) = (1/4)L - (1/2)B \tag{1.2}$$

The value of F can be computed observing that the bank makes money if the credit line is not drawn, and loses money if the firm faces an overrun: for the value of F shown above the bank's expected profit is zero. Note that the credit line must be pre-arranged in $t = 0$. Come $t = 1$ financing the overrun is a money-losing operation: the bank would not be willing to do it unless it is bound by a contract: an example of a situation of time inconsistency. Outside investors will still finance the project in $t = 0$. They will also pay for the commitment fee: you can check this noting that they pay $B + F =$

$1/2B + 1/4L$ in $t = 0$ and their expected return is also $(1/2)\ P = 1/2B + 1/4L$; thus they come out even. The bank is also fine, provided that it diversifies the credit lines across all firms in the economy, and that the overruns net out in the aggregate, i.e., provided that the sum of all that is drawn from the credit lines in $t = 1$ is zero. In other words, provided that there is no aggregate shock to the economy. In this case the bank makes a profit of F on one half of the firms to which it has extended credit lines (we are assuming that all firms are identical) and a loss of $-F + (L - P) = F$ on one half of the firms who draw the lines. Thus it would seem that if liquidity shocks are uncorrelated there is always enough inside liquidity and no project will ever be abandoned.

What could go wrong? Inside liquidity need not only be sufficient in the aggregate: as we have seen it also needs to be dispatched to those who need it This condition breaks down if 'banks' are not perfectly diversified. In the previous example there is only one bank: thus, if shocks are idiosyncratic and cancel out in the aggregate, the bank is perfectly diversified by definition. But consider a situation where there is more than one bank and banks are not perfectly diversified. Consider an extreme case: assume there are only two firms and two banks. Each bank extends a credit line to one firm only. There is no aggregate liquidity shock: one firm faces an overrun and thus draws on its credit line; the other pays the commitment fee but does not draw on its credit line because it does not face an overrun. In this case one bank makes a profit of F, the other a loss of F. More importantly, the firm which faces an overrun cannot rely on its bank to finance it and must fold up its project. There is still enough liquidity in the aggregate, but it is not dispatched to the firm that needs it because the bank which makes a profit has no incentive to give it up and transfer it to the other bank so that this can deliver on its committed credit line.[6]

[6] The literature has investigated many reasons why the dispatching of inside liquidity may break down. Adverse selection: if you sell it, it must be a lemon, thus I don't buy it. Bad news (Dang, Gorton and Hölmstrom, 2009) which not only lowers the value of an asset but gives rise to adverse selection problems resulting in secondary markets drying up. Fire sales. Institutions which hoard liquidity to be ready to snap up the assets of distressed firms. Gambling for resurrection: distressed firms have the assets and could sell them to deep-pocket investors, but because the price of these assets is low, they rather wait.

The lesson from this example is that inside liquidity may be insufficient to prevent liquidation of otherwise productive projects, even absent macroeconomic shocks: financial fragility can result in productive capital being destroyed. The central bank has two ways to deal with this. It can use regulation to make sure that all banks are perfectly diversified, so that none is exposed to idiosyncratic shocks. This is the superior, though probably unrealistic solution. Alternatively, if regulation fails to achieve perfect diversification, it can step in to provide outside liquidity to those firms to which liquidity fails to be dispatched.

The fragility of securities markets

Our second example uses the same analytical framework used in the first: it is also inspired by Hölmstrom and Tirole (2011). But here we extend that framework to study the liquidity shocks that might affect, rather than an entrepreneur, a portfolio manager. Our purpose is to show how financial intermediaries may be subject to 'runs' in a manner that is similar to the 'runs on banks' studied in Diamond and Dybvig (1983). There are still three periods. At date 0, a fund manager creates a fund purchasing a set of securities to construct a portfolio. The total outlay for the purchase of the securities is I, which the fund manager finances borrowing B from investors and contributing E of his own, so that $B+E = I$. In $t = 2$ (and not before) the portfolio yields a return greater than I which is distributed between the fund manager and the investors (as above in such a way as to make sure that the manager puts in enough effort). In $t = 1$ the fund is subject to a random liquidity shock: with probability $1/2$ investors withdraw B. Why would this happen? In $t = 0$ investors know that the securities yield a return only in $t = 2$, but they also know that there is the chance of an early withdrawal. (This is a short-cut that should be more carefully thought out. Investors could suddenly discover that instead of 'patient', they are 'impatient' and want to withdraw, maybe there is a shock to their preferences, maybe some macro news has scared them.) Whatever the reason, we assume it does not alter the expected return on the portfolio. In $t = 0$ the pledgeable income (following the same logic of the previous example) is

$$P = B + 1/2B = 1.5B \tag{1.3}$$

To attract investors the fund must promise that they will at least break even: investors contribute B in $t=0$ and again B with probability $1/2$ in $t = 1$. Thus in $t = 0$ they must be promised at least $1.5\ B$. How can the fund manager liquidate his investors if he needs to in $t = 1$? He could either sell the portfolio or raise fresh funds from new investors. Because $P = 1.5\ B > B$, he will always be able to survive the liquidity shock by attracting new investors: he needs to raise B and can promise $P > B$. So, this case is not particularly interesting. But let's instead assume that the option of attracting new investors is ruled out, perhaps because when some investors withdraw nobody is willing to come in. Then the only way for the fund manager to survive the withdrawals is to sell the portfolio. Let p be the price at which the portfolio can be sold in $t = 1$. Assume that p is a firesale price, so that $p < P$: in other words, p is lower than the 'value' of the portfolio in $t = 1$. The minimum price that allows the fund manager to survive is $p \geq B$. For $p < B$, anytime investors want to get out in $t = 1$, the intermediary is broke. Thus there are multiple equilibria which depend on investors' preferences. The possibility that a fund subject to sudden withdrawals may fail can have real effects and result, as in the previous example, in a destruction of capital. Here again the central bank can address this fragility by stepping in to provide outside liquidity to the funds that experience sudden withdrawals.

Excessive liquidity transformation

In the previous section we took the amount of liquidity transformation as given and discussed why it makes financial markets fragile. We now move on and allow for monetary policy to determine the amount of liquidity transformation. Drawing on a contribution by Jeremy Stein (2011) we show that the central bank may induce 'excessive' liquidity transformation, thus contributing to making markets more fragile. The Stein model considers a bank which faces the following investment opportunity: by investing I in $t = 0$, if a 'good state' prevails (which happens with probability p) total output at time 2 is $f(I) > I$. If instead a 'bad state' prevails, total expected output in $t = 2$ is $\lambda I \leq I$, where λ could be as low as 0. The state of the world, good or bad, is revealed in $t = 1$. At that time it is possible for the bank to sell its investment at a (possibly firesale price) k, where $0 \leq k \leq 1$: The bank finances I borrowing from investors. It can do so by issuing either short-term (maturing in $t = 1$) or long-term (maturing in $t = 2$) debt claims. Long term debt is risky because there is a positive probability of the assets yielding zero output at time two. Short term deposits pay a return R^M and are by assumption riskless: they are de-facto 'private money'. Because the interest rate on risky assets is above the interest rate on riskless assets, the bank has an incentive to finance as much as possible of its project with short term debt: by doing this it appropriates the value that investors attribute to the services of 'money', i.e., to liquidity. The constraint is that 'money' must always be repaid, no matter what the state of the world is in period 1. Let m be the fraction of the project financed issuing short-term deposits. In $t = 1$ the bank owes its short-term creditors $mIR^M \equiv M$. For the bank to meet this promise in the bad state by selling assets (i.e., the project it has financed) it must be that:

$$M \leq k\lambda I \tag{1.4}$$

which implies an upper bound for m

$$m \leq m^{\max} = \frac{k\lambda}{R^M} \tag{1.5}$$

so that

$$M^{\max} = \frac{k\lambda I}{R^M} \tag{1.6}$$

$m = m^{max}$ whenever the difference between the return on risky and riskless assets is sufficiently high, i.e., when the bank's incentive to issue short term liabilities is large. Note that for $m = m^{max}$ the bank faces a collateral constraint: the only way it can raise M (and thus appropriate the value investors attribute to the services of liquidity) is to raise I. To issue additional short term debt it must invest more which is the way it can raise its collateral. As Stein observes, the collateral constraint gives rise to an externality which can be understood as follows. When a given bank raises I, and thus M, it takes into account the fact that, in the bad state, this will force it to sell more assets at a discount in order to pay off its own short-term debt. What it fails to internalize, however, is that by raising M it reduces the equilibrium value of k, thus lowering the collateral value of all other bank's assets. The bottom line is that for a large-enough spread between the return on risky and riskless assets the bank engages in inefficient liquidity transformation.

What happens in a 'bad' state when the bank, to make good on M, needs to sell its project at a price k ? Who will buy it, and how is k determined? In $t = 1$ there will be new investors in the economy and new projects to be financed (new to distinguish them from the investors who have financed the 'old' project in $t = 0$). They are the buyers of the old project. Let W be the total resources of the new investors, and $g(W)$ the output of the new projects they could finance. In principle these investors could use all of W to finance new projects, obtaining a marginal return $g'(W)$. If instead they buy M from the bank they will only invest $(W–M)$ and their return will fall to $g'(W – M)<g'(W)$. In the bad state the need to reimburse M crowds out good projects. To convince the new investors to buy M, $g'(W–M)$ must equal the marginal return from buying the old project from the bank: this pins down the firesale discount k:[7]

$$g'(W-M)=\frac{1}{k} \tag{1.7}$$

As in the examples of the previous section, when a bad state occurs, and the spread between risky and riskless assets induces excessive liquidity transformation, the central bank can limit the crowding out by injecting outside liquidity, that is by supplying M (or a fraction of M) to the bank, thus limiting how much of the project it will need to sell. But the model has an additional implication for monetary policy[8]: the smaller the difference between the return on

[7] We are left with the problem of determining the optimal levels of m and of I. We show this in Appendix 1.

[8] The model has another interesting, though somewhat paradoxical implication. A way to induce the bank to limit m is to allow it to increase the riskiness of its balance sheet, for example by holding 'derivatives', i.e., assets that resemble pure 'bets'. When a bank holds a 'bet', its balance sheet becomes more fragile, and this is normally bad. But there is also a silver lining. The 'bet' reduces the amount of safe deposits the bank can issue, and thus the distortion associated with this incentive. There are two reasons why a bank may decide to hold 'bets'. They may be part of its proprietary trading

risky assets and the risk-free rate, the smaller the bank's incentive to increase I in order to relax its collateral constraint; in other words, the smaller is the incentive to engage in excessive liquidity transformation. There is a level of this spread below which liquidity transformation is no longer 'excessive'.

We shall discuss what this implies for central banks in the next section.

Liquidity Transformation, Financial System Reforms and Monetary Policy

The examples in the previous sections have illustrated the basic fragility of financial intermediation which arises from the possibility that investors rush to liquidity. This risk is compounded by the possibility that monetary policy might induce excessive liquidity transformation. In this section we start by asking if financial system reforms can limit financial fragility; we shall then discuss how central banks can avoid subsidizing liquidity transformation.

Financial system reforms

The basic ingredients of financial fragility are liquidity transformation as well as asymmetric information. Liquidity transformation is itself a good thing, because it allows access to more productive technologies. Imperfect information is a characteristic of any financial system where the providers of funds are different from the users of funds. In addition, the imperfect information problem is multiplied the greater is the distance between users and providers of funds. With the multiple

activities: in this case the bank holds pure bets with the purpose of affecting the risk profile of its own equity. Alternatively it may hold them as part of the services it offers to its clients: one example is a bank that sells insurance (options) that allows a firm to protect itself against, for instance, fluctuations in commodity prices. By doing this the bank exposes itself to fluctuations in such prices. In this case 'bets' have a social value: for instance they can raise the productivity of the technology the bank's clients operate. We analyze this case in Appendix 2.

layers of intermediaries and the pervasiveness of securities markets, the potential guises liquidity or financial crises can take also multiply.

Another factor contributing to the spreading as well as the magnification of liquidity crises is, in the intermediaries' business, the process of risk management. Exposures to financial risks are hedged dynamically (or equivalently through contingent derivative contracts), thus giving rise to nonlinear reactions to price changes. Furthermore, risk management leads to contagion, as losses in some markets lead to a deficit of capital that can only be recouped through the liquidation of assets not necessarily related to the original losses.

These observations highlight, just as the analytical examples in the previous sections, that liquidity crises are as much outside the banking system as within the system itself. The evolution of the financial system outside of banks is well illustrated by Gorton (2007). Banks have exited the traditional borrowing/lending business (whereby loans are held in the balance sheet until maturity) because it is not any more profitable. They sell their loans through various structures, including special investment vehicles (SIVs), asset backed securities (ABSs), collateralized loan obligations or collateralized bond obligations (CLOs, CBOs). The different capital tranches of these structures are bought by different classes of investors, including long term investors like pension funds, money market mutual funds and hedge funds. As far as fund-raising is concerned, banks use the repo market, where cash is exchanged with securities in a buy/sell type contract: the securities provided as collateral are those created through the various structures mentioned above, which in part banks retain for themselves. According to Gorton, the size of the repo market in the United States has reached roughly US$ 12 trillion. A liquidity crisis in this market, a run on the banks, involves an increase in margin requirements in repo transactions, leading to liquidations of the underlying assets and therefore further increases in margin requirements (these illiquidity spirals have been described, among others, by Brunnermeier and Pedersen, 2008). The final observation needed to describe the nature of financial crises in the contemporary financial system is that, especially through risk management and the development of over-the-counter derivative contracts, the number and frequency of transactions in securities has increased tremendously (the total value of securities transactions in the United States is valued in the quadrillions): with it, counterparty risk has multiplied. As a result, the potential of chains of failures has gone up.

Recognizing the increased fragility of the financial system due to the spreading and multiplying of liquidity risk well outside the banking system, a number of authors, including one author of this chapter (Giovannini, 2010), have suggested structural reforms to make the financial system less prone to crises. These reform proposals include:

1. a decrease of counterparty risk in the financial system through a much wider use of central counterparties, which play the role of 'black holes' of counterparty risk in the system, as well as the adoption of orderly resolution rules for the large balance sheets of financial intermediaries.
2. a role for regulatory authorities to mitigate the information problem by accessing all data in securities and derivatives market transactions and positions, as well as risk positions of all financial intermediaries, by elaborating an aggregate picture of systemic risks, and by publishing their analysis and (aggregate) information for all market participants to see. This way, authorities would be in a position of carrying out their systemic risk manager duties much more effectively than in the recent past.
3. the re-establishment of an appropriate correspondence between the regulatory framework that defines different financial organizations in the marketplace and the functions they effectively perform (to avoid conflicts of interest, excessive risk taking, implicit puts to the government, etc.): a concept that inspires the so-called 'Volcker rule', as well as initiatives to make the regulatory framework for hedge funds converge onshore.

Low interest rate traps

Structural reforms can strengthen the financial system and decrease the risk of liquidity crises, but they cannot eliminate them completely. The reason is that liquidity breakdowns can only be eliminated by eliminating liquidity transformation. By now it should be apparent that liquidity transformation is a function that almost defines the financial system. Thus, even successful structural reforms do not take away from our conclusion in the previous section, that is, interest rates have to reflect the risk of financial crises. In other words, all actors in the marketplace have to know that liquidity could be less than what they observe in normal times, because there is always the possibility of breakdowns: interest rates have to properly reflect this. Discussions of monetary policy in the years preceding the crisis (including Bernanke 2010) mostly focus on the extent to which interest rates have been set according to the 'Taylor rule'. They concentrate on the variables in the Taylor rule – the deviation of inflation expectations from the central bank target – but tend to overlook the other variable in the rule: the real rate of interest. Empirical applications of the Taylor rule tend to use, for the real rate, a long average of past real rates – the argument being that since the real rate is a stationary variable the average of past real rates is a good proxy for the equilibrium real rate today. This argument, however, overlooks the point made in the previous section, namely that the ex-ante real rate affects the banks' incentive to engage in liquidity transformation. To the extent that this incentive has changed over time (or has been overlooked when setting interest rates in the past) so should the ex-ante real rate. If central banks set interest rates overlooking the risk of financial crises, rates in 'normal times' will be too low and liquidity transformation will be subsidized, as recent experience has shown. This could push the economy into a low-interest-rate trap. Low interest rates induce too much risk taking and increase the probability of crises. These crises, in turn, require low interest rates to maintain the financial system alive. Raising rates becomes extremely difficult in a severely weakened financial system, so monetary authorities remain stuck in a low interest rates equilibrium.

Summing Up and Looking Forward

Two main messages come out from our paper. Financial systems are inherently fragile because the reason for their fragility is the very function which makes a financial system so precious: liquidity transformation. Regulatory reforms can strengthen the financial system and decrease the risk of liquidity crises, but they cannot eliminate it completely. This leaves monetary policy with a very important task. In a framework that recognizes the interactions between monetary policy and liquidity transformation, 'optimal' monetary policy would consist of a modified Taylor rule in which the real rate reflects the possibility of liquidity crises and recognizes that liquidity transformation gets subsidized. Failure to recognize this point risks leading the economy into a low interest rate trap: low interest rates induce too much risk taking and increase the probability of crises. These crises, in turn, require low interest rates to maintain the financial system alive. Raising rates becomes extremely difficult in a severely weakened financial system, so monetary authorities remain stuck in a low interest rates trap. This seems a reasonable description of the situation we have experienced throughout the past decade. What is the empirical implication of the analysis in this paper? What does it mean that the short term real interest rate should not subsidize liquidity transformation? And importantly, if what matters for the possibility of such a subsidy is the spread between the policy rate and the return on risky assets, does the central bank have control over it? These are issues for further research. As concerns the first question one way to go about it could be investigating whether different monetary policy rules (across time or countries) are correlated with differences in the duration of investment: in particular the share of residential investment in total investment or in GDP (for an attempt see Dew-Becker 2009). The idea being that a monetary policy that subsidizes liquidity transformation might be associated with a longer duration of investment and a higher share of residential investment.

Appendix 1

Determining the optimal values of *m* and *M*

The bank's profits are:

$$\left[pf(I)+(1-p)\lambda I-IR^{B}\right]-mI\left(R^{B}-R^{M}\right)-(1-p)zmIR^{B}$$

The FOC with respect to *m*, the share of the project financed with short term debt, is:

$$I\left[\left(R^B - R^M\right) - (1-p)\, zR^B\right]$$

If the excess return on the risky asset, R^B, over the return on money R^M, is larger than the expected losses associated with a firesale, $(1-p)\, zR^M$, m has a corner solution

$$m^* = m^{\max} = \frac{k\lambda}{R^M}$$

The optimal quantity of *M* (note that finding a *max* with respect to *M* or *I* is equivalent) is determined by the following FOC

$$\left[pf' + (1-p)\lambda - R^B\right]\frac{dI}{dM} + \frac{R^B - R^M}{R^M} - z(1-p)$$

If $m = m^{max}$ the sum of the last two terms is positive: the optimal level of *M* then requires the first term to be negative: this means that the optimal level of *I*, I^*; is larger than the level that would be chosen if the project was financed only with risky debt at the rate R^B, that is $I^* > I^B$. The intuition for this result is as follows. For $m = m^{max}$ the bank runs up against a collateral constraint: it can raise *M* (thus appropriating the social value of money) only by investing more, that is raising *I*, because *m* is fixed. It can do this choosing $I^* > I^B$, the amount the bank would invest if it financed the project only with risky bonds.

I^* is not only larger than I^B: it is also larger than the level a social planner would choose for a given spread $R^B - R^M$. To see this note that a social planner would maximize

$$U = \left[pf(I) + (1-p)\lambda I - IR^B\right] - M\frac{R^B - R^M}{R^M} + E\left[g(K) - K\right]$$

The social planner's FOC with respect to *M* is identical to the FOC faced by the individual bank with one difference

$$\left.\frac{dM}{dI}\right|_{planner} = \frac{k\lambda}{1-\lambda I\dfrac{dk}{dM}} < \left.\frac{dM}{dI}\right|_{bank} = k\lambda$$

when a single bank raises its investment, and thus the amount of money it issues, it takes *k* as given. For this to happen, that is for *k* not to change, all other banks must compensate lowering the money they create. The externality works like in a Cournot equilibrium: one firm raises its output, the other firm cuts it, but by less, so that aggregate output increases and the price falls. This is the externality the social planner corrects, thus the result that the planner, for any increase in *I*, would raise *M* by less.

Appendix 2

Bets, capital and private money

Consider the effect of introducing a 'bets' in the balance sheet of the bank studied in Stein (2010). Let *B* be the amount of 'bets' the bank holds. 'bets' are securities which yield *B* with probability α and *-B* with probability *(1-*α*)*. Define $b \equiv B/I$. By raising the risk of the balance sheet, *B* reduces m^{max}. By how much depends on whether it is a pure 'bet', or a 'bet' held to provide a service to the bank's clients. We shall consider the two cases separately.

- A pure 'bet' with no direct value

  The 'bet' has no value, i.e., it does not affect the return on the project the bank finances. In this case

$$m^{\max} = \frac{k\lambda - B/I}{R^M} < \frac{k\lambda}{R^M}$$

  the higher *B*, the lower m^{max}: the 'bet' reduces the externality moving the share of short term financing closer to the level a social planner would choose.

- A 'bet' which increases the amount a firm can invest for any given amount of financing

The way we model this is as follows. Think of this 'bet' as insurance the bank sells to a firm. Insurance makes I less risky. Assume then that the project yields $f(I)$ by investing $I(1-b)<I$.
In this case

$$m^{\max} = \frac{k\lambda - b}{R^M(1-b)}$$

Now the bank has two ways to increase the value of the collateral and issue more short term debt: it can raise I, or it can raise B. For $B = 0$, the collateral is, as before, $k\lambda I$. For $B > 0$ it is $\frac{k\lambda - b}{(1-b)}$.
The total amount of safe demand deposits the bank can issue, M, is $M = m^{\max} I/1-b$ and increases with b provided $k\lambda > b$

$$\frac{dM}{db} = I\frac{k\lambda - b}{(1-b)^2}$$

Note that this condition is reasonable because it compares the value of the collateral that is constraining the amount of short term debt the bank can issue, $k\lambda$, with b that measures the crowding out effect. As b raises, M rises provided $k\lambda > b$. The 'bet' has two effects, both of which are a reasonable description of the consequences of allowing the bank to take up risks that help the economy insure: it crowds out short term debt, thus working against the externality, and it expands lending allowing it to issue a larger amount of short term debt.

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