Securitisation and Financial Stability*

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Abstract

A widespread opinion before the credit crisis of 2007/8 was that securitisation enhances financial stability by dispersing credit risk. After the credit crisis, securitisation was blamed for allowing the "hot potato" of bad loans to be passed to unsuspecting investors. Both views miss the endogeneity of credit supply. Securitisation enables credit expansion through higher leverage of the financial system as a whole. Securitisation by itself may not enhance financial stability if the imperative to expand assets drives down lending standards. The "hot potato" of bad loans sits in the financial system on the balance sheets of large banks rather than being sold on to final investors, since the aim of financial intermediaries is to expand lending in order to utilise slack in balance sheet capacity.

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1. Introduction

There are two pieces of received wisdom concerning securitisation - one old and one new. The old view (prevalent before outbreak of the credit crisis of 2007/8) emphasized the positive role played by securitisation in dispersing credit risk, thereby enhancing the resilience of the financial system to defaults by borrowers. The subsequent credit crisis has somewhat tarnished this positive image.[1] In its place, there is a new received wisdom which emphasizes the distorted incentives that developed at all stages of the securitisation process, and which allowed the "hot potato" of bad loans to pass through the financial system to be held finally in the hands of unsuspecting final investors.

Although both views of securitisation (old and new, positive and negative) are appealing at a superficial level, they both neglect the endogeneity of credit supply. Financial intermediaries manage their balance sheets actively in response to shifts in measured risks. The supply of credit is the outcome of such decisions, and depends sensitively on key attributes of intermediaries' balance sheets.

Three attributes merit special mention - equity, leverage and funding source. The equity of a financial intermediary is its risk capital that can absorb potential losses. Leverage is the ratio of total assets to equity, and is a reflection of the constraints placed on the financial intermediary by its creditors on the level of exposure for each dollar of its equity. Finally, the funding source matters for the total credit supplied by the financial intermediary sector as a whole to the ultimate borrowers.

At the aggregate sector level (i.e. once the claims and obligations between leveraged entities have been netted out), the lending to ultimate borrowers must be funded either from the equity of the intermediary sector or by borrowing from

[1] See BIS (2008), Brunnermeier (2008), Greenlaw et al. (2008) or IMF (2008) for an account of the credit crisis of 2007/8.

creditors *outside* the intermediary sector. For any fixed profile of equity and leverage across the banks, the supply of credit to ultimate borrowers is larger when the banks borrow more from creditors outside the banking system.

In a traditional banking system that intermediates between retail depositors and ultimate borrowers, the total quantity of deposits represents the obligation of the banking system to creditors outside the banking system. However, securitisation opens up potentially new sources of funding for the banking system by tapping new creditors. The new creditors are those who buy mortgage-backed securities (MBSs), claims that are written on MBSs such as collateralised debt obligations (CDOs), and (one step removed) those who buy the asset-backed commercial paper (ABCP) that are ultimately backed by CDOs and MBSs.[2] The new creditors who buy the securitised claims include pension funds, mutual funds and insurance companies, as well as foreign investors such as foreign central banks. Indeed, we will see shortly that foreign central banks have been an important funding source for residential mortgage lending in the United States. We will also examine some more partial evidence for the United Kingdom from balance sheet of Northern Rock, the UK mortgage bank which failed in 2007.

Although securitisation may *facilitate* greater credit supply to ultimate borrowers at the aggregate level, the choice to supply credit is taken by the constituents of the banking system taken as a whole. For a financial intermediary, its return on equity is magnified by leverage. To the extent that it wishes to maximize its return on equity, it will attempt to maintain the highest level of leverage consistent with limits set by creditors (for instance, through the "haircuts" on repurchase agreements) or self-imposed risk constraints. As measured risk fluctuates, so will leverage itself. In benign financial market conditions when

[2] See Gorton and Souleles (2006) for a description of special purpose vehicles involved in the securitisation process in the US.

measured risks are low, financial intermediaries expand balance sheets as they increase leverage. Although the intermediary could increase leverage in other ways - for instance, returning equity to shareholders, buying back equity by issuing long-term debt - the evidence suggests that they tend to keep equity intact and adjust the size of total assets (see Adrian and Shin (2007, 2008b)). As balance sheets expand, new borrowers must be found. When all prime borrowers have a mortgage, but still balance sheets need to expand, then banks have to lower their lending standards in order to lend to subprime borrowers. The seeds of the subsequent downturn in the credit cycle are thus sown.

When the downturn arrives, the bad loans are either sitting on the balance sheets of the large financial intermediaries, or they are in special purpose vehicles (SPVs) that are sponsored by them. This is so, since the bad loans were taken on precisely in order to utilise the slack on their balance sheets. Although final investors such as pension funds and insurance companies will suffer losses, too, the large financial intermediaries are more exposed in the sense that they face the danger of seeing their capital wiped out. The severity of the credit crisis of 2007/8 lies precisely in the fact that the bad loans were *not* all passed on to final investors. Instead, the "hot potato" sits inside the financial system, on the balance sheet of the largest, and most sophisticated financial intermediaries.

The outline of this paper is as follows. I begin with some background on securitisation, and construct an accounting framework of the financial system as a network of inter-linked balance sheets. When this accounting framework is combined with a model of leverage based on value at risk (VaR), it is possible to model a lending boom fuelled by declines in measured risks. I conclude with a discussion of the implications for financial stability.

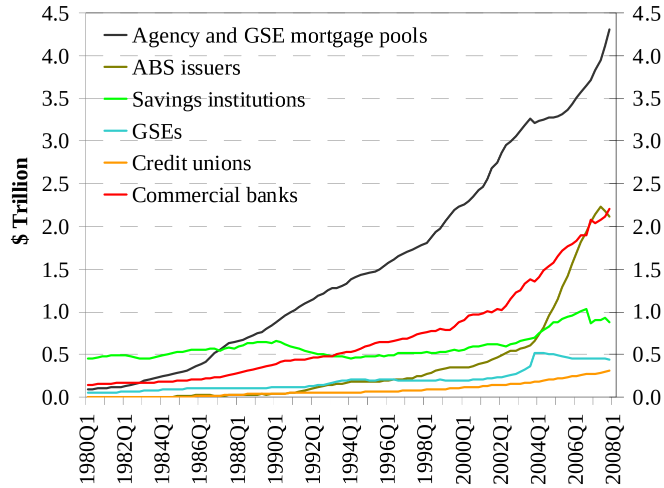

Figure 2.1: US Home Mortgage Assets (1980Q1 - 2008Q1): Flow of Funds, US Federal Reserve.

2. Background

Securitisation has played a key role in the growth of residential mortgage lending, especially in the United States. Figure 2.1 plots the total outstanding US home mortgage assets held by various classes of financial institutions from 1980. Even as recently as the early 1980s, banks and savings institutions held the bulk of home mortgages. Since then, the mortgage pools of the government sponsored enterprises (GSEs) such as Fannie Mae and Freddie Mac have become the largest holder of residential mortgages. Also noticeable are the securitisation vehicles classified under asset backed securities (ABS) issuers. The ABS issuers hold mortgages that do not conform to the GSE standards, and hence contains the subprime mortgages as well as large mortgages ("jumbo" mortgages) that exceed the upper threshold on the GSE conforming mortgages.

Figure 2.2 is an aggregate series that distinguishes the "bank-based" holdings

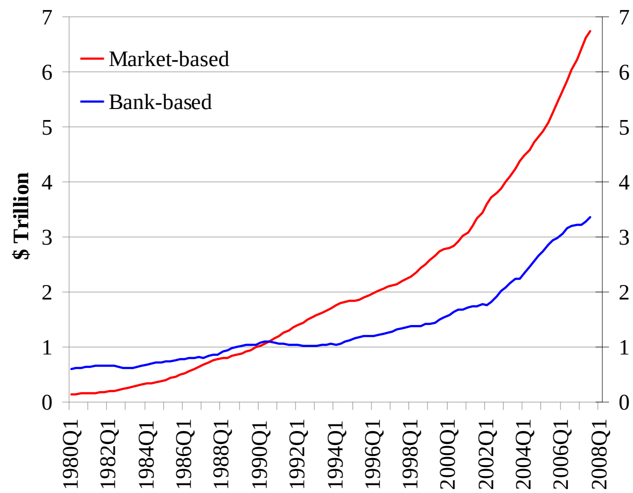

Figure 2.2: Bank-Based and Market-Based Home Mortgage Holdings (1980Q1 - 2008Q1): Flow of Funds, US Federal Reserve

of residential mortgages from the "market-based" holdings. The latter is the sum of the holdings of the government sponsored enterprises, the GSE mortgage pools and the private label ABS issuers. The bank-based series is the sum of the remaining three categories. We can see that the market-based series overtook the bank-based series in 1990, and now accounts for two thirds of approximately 11 trillion dollars' worth of residential mortgages outstanding.

Securitisation had long been seen as a positive development for the resilience of the financial system by enabling the dispersion of credit risk. However, since the onset of the credit crisis of 2007/8, a less sympathetic view of securitisation has gained support that emphasizes the multi-layered agency problems that took hold at every stage of the securitisation process, starting with the origination of the loan to the sale, warehousing and securitisation as well as the role of the credit rating agencies in the process.[3] We could dub this less charitable view the "hot potato"

[3]A comprehensive survey of the securitisation process for subprime mortgages is given by

hypothesis, and it has figured frequently in speeches given by policy makers on the credit crisis.[4] The motto would be that there is always a greater fool in the chain who will buy the bad loan. At the end of the chain, according to this view, is the hapless final investor who ends up holding the hot potato and suffers the eventual loss. A celebrated anonymous cartoon strip has circulated widely on the internet[5] depicting a hapless official from a Norwegian municipality in conversation with a broker after suffering losses on subprime mortgage securities. There is also mounting empirical evidence that lending standards had been lowered progressively in the run-up to the credit crisis of 2007 (see Demyanyk and van Hemert (2007), Mian and Sufi (2007) and Keys et al. (2007)).

It is clear that final investors who buy claims backed by bad assets will suffer losses. However, it is important to draw a distinction between selling a bad loan down the chain and issuing liabilities backed by bad loans. By selling a bad loan, you get rid of the bad loan from your balance sheet. In this sense, the hot potato is passed down the chain to the greater fool next in the chain. However, the second action has a different consequence. By issuing liabilities against bad loans, you do not get rid of the bad loan. The hot potato is sitting in the financial system, on the books of the special purpose vehicles (SPVs). Although the special purpose vehicles are separate legal entities from the large financial intermediaries that sponsor them, the finanical intermediaries have exposures to them from liquidity enhancements and various forms of retained interest (see Gorton and Souleles (2006)). Thus, far from passing the hot potato down the chain to the greater fool next in the chain, the large financial intermediaries end up keeping the hot potato. In effect, the large financial intermediaries are the last in the chain. They are the

Ashcraft and Schuermann (2008) who details the specific agency problems at seven points in the securitisation chain.

[4] See, for instance, Gieve (2008) and Mishkin (2008) among others.

[5] For instance, http://bigpicture.typepad.com/comments/2008/02/how-subprime-re.html

greatest fool. While the final investors such as the famed Norwegian municipality will end up losing money, the financial intermediaries that sponsored the SPVs are in danger of larger losses. Since the intermediaries are leveraged, they are in danger of having their equity wiped out.

Indeed, Greenlaw et al. (2008) report that of the approximately 1.4 trillion dollar total exposure to subprime mortgages, around half of the potential losses are borne by US leveraged financial institutions, such as commercial banks, investment banks and hedge funds. Gorton (2008) also notes that financial intermediaries have borne a large share of the total losses. When foreign leveraged institutions are included, the total rises to two thirds. This raises the following important question. Why did apparently sophisticated banks act as the "greatest fool"? In the rest of the paper, I outline a framework that addresses this question.

3. An Accounting Framework

Financial intermediaries play the role both as a lender, but also as a borrower. In what follows, I describe an accounting framework to take account of the interlocking claims and obligations. There are $n+1$ entities in financial system, where n of them are leveraged institutions (referred to as "banks" for convenience) and one unleveraged sector (indexed by $n+1$), which aggregates the balance sheets of unleveraged institutions such as insurance companies, pension funds and mutual funds, as well as household investors or foreign central banks. There is also an "end-user" sector who are the ultimate borrowers. For our purposes, we may consider the ultimate borrowers as households who buy a house financed with a mortgage.

Denote by $\bar{y}_i$ the face value of claims held by bank i against such end-user borrowers. As well as the end-user loans, there are also claims between members of the financial system. The liability of one party in the system will be the asset of another party. Denote by $\bar{x}_i$ the face value of the obligation of bank i, and by π_{ij} the share of bank i's obligations that are held by bank j. Then, denoting by $\bar{e}_i$ the notional value of equity of bank i, the balance sheet identity of bank i in terms of face values is:

$$\bar{y}_i + \sum_{j=1}^{n} \bar{x}_j \pi_{ji} = \bar{x}_i + \bar{e}_i \tag{3.1}$$

The left hand side of (3.1) is the total assets of bank i in notional values, consisting of the loans made to end-users $\bar{y}_i$, and the claims held against the other leveraged entities (the "banks") in the financial system, $\sum_{j=1}^{n} \bar{x}_j \pi_{ji}$. The right hand side of (3.1) gives the total liabilities of bank i in notional values, and consists of the total promised repayment $\bar{x}_i$ by bank i plus the notional equity $\bar{e}_i$ that equates the two sides of the balance sheets. The interlocking claims and obligations can be depicted in terms of the following table, where $\bar{x}_{ij}$ denotes the notional value of bank i's obligations to bank j.

	bank 1	bank 2	$\cdots$	bank n	outside	debt
bank 1	0	$\bar{x}_{12}$	$\cdots$	$\bar{x}_{1n}$	$\bar{x}_{1,n+1}$	$\bar{x}_1$
bank 2	$\bar{x}_{21}$	0		$\bar{x}_{2n}$	$\bar{x}_{2,n+1}$	$\bar{x}_2$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	
bank n	$\bar{x}_{n1}$	$\bar{x}_{n2}$	$\cdots$	0	$\bar{x}_{n,n+1}$	$\bar{x}_n$
end-user loans	$\bar{y}_1$	$\bar{y}_2$	$\cdots$	$\bar{y}_n$		
total assets	$\bar{a}_1$	$\bar{a}_2$		$\bar{a}_n$		

Summing the ith row of the matrix gives the total liabilities of bank i, since it sums the obligations of bank i to other banks and to the long-only investors (sector $n+1$). The sum of the entries in the ith column of the matrix gives the total notional assets of bank i, since it sums the claims that bank i has on all other banks in the system, plus the loans it has made to the end-users. The total notional assets of bank i are denoted as $\bar{a}_i$.

3.1. Credit Risk

To begin with, suppose there are two dates, date 0 and date 1. Loans made at date 0 and are repaid at date 1. The loans made to the end-users are risky and banks face credit risk. Credit risk follows the familiar Vasicek (2002) one factor model, which is widely used and has been adopted as the backbone of the Basel II capital regulations[6]. Under the Vasicek one factor model, the end-user borrower j of bank i repays the loan when the realisation of random variable Z_{ij} is non-negative, where Z_{ij} is defined as

$$Z_{ij} = -\Phi^{-1}(p_i) + \sqrt{\rho}Y + \sqrt{1-\rho}X_{ij} \tag{3.2}$$

where $\Phi(.)$ is the c.d.f. of the standard normal, Y and $\{X_{ij}\}$ are mutually independent standard normal random variables, and ρ and p_i are constants. Y has the interpretation of the common risk factor and X_{ij} is the idiosyncratic risk factor. The probability of default of any borrower j of bank i is p_i since

$$\begin{aligned} \Pr(Z_{ij} < 0) &= \Pr\left(\sqrt{\rho}Y + \sqrt{1-\rho}X_{ij} < \Phi^{-1}(p_i)\right) \\ &= \Phi\left(\Phi^{-1}(p_i)\right) = p_i \end{aligned}$$

Conditional on the common factor Y, defaults are independent across borrowers, and the parameter ρ gives the ex ante correlation in defaults between any two loans made by bank i.

Suppose that bank i's portfolio includes N loans to end-users each with face value $\bar{y}_i/N$. But letting N become large, the loan portfolio to end-users consists

[6] See also Alizalde and Repullo (2006) for an application of the Vasicek model in a model of banking competition.

of many small loans whose defaults are independent conditional on the realisation of Y. By the law of large numbers, the repayment w_i on the loan book of face value $\bar{y}_i$ then becomes a determinstic function of Y. In other words,

$$
\begin{aligned}
w_i(Y) &\equiv \bar{y}_i \Pr(Z_{ij} \geq 0|Y) \\
&= \bar{y}_i \Pr\left(Y\sqrt{\rho} + X_{ij}\sqrt{1-\rho} \geq \Phi^{-1}(p_i)\right) \\
&= \bar{y}_i \Phi\left(\frac{Y\sqrt{\rho} - \Phi^{-1}(p_i)}{\sqrt{1-\rho}}\right)
\end{aligned}
$$

The c.d.f. over the repayment on bank i's loan book is thus

$$
\begin{aligned}
F_i(z) &= \Pr(w_i(Y) \leq z) \\
&= \Pr\left(Y \leq w_i^{-1}(z)\right) \\
&= \Phi\left(\frac{\Phi^{-1}(p_i) + \sqrt{1-\rho}\,\Phi^{-1}\left(\frac{z}{\bar{y}_i}\right)}{\sqrt{\rho}}\right) \qquad (3.3)
\end{aligned}
$$

Note the following features. A change in p_i (the probability of default on a particular loan made by bank i) implies first degree stochastic dominance shift in the repayment density. A fall in p_i pushes down the c.d.f., implying a first-degree stochastic shift to the right in repayments. When p_i is fixed, the mean repayment remains unchanged. However, a change in the parameter ρ keeping p_i fixed implies a second degree stochastic dominance shift in the repayment density. An increase in ρ is associated with a mean-preserving spread of the repayment density, making the loan book more risky.

3.2. Realized Values of Debt

The realized value of repayment on the loans to end-users will determine the realized value of the claims held between the banks, since the ability of one bank to fulfil its promise will depend on the resources it has to meet its obligations.

Let us use the hat notation "ˆ" to denote realized values at date 1. Thus, $\hat{y}_i$ is the realized repayment on bank i's loans to end-users, $\hat{x}_i$ is the realized repayment by bank i and so on. Assume that all debt is of equal seniority, so that if $\hat{x}_i < \bar{x}_i$, then bank j receives share π_{ij} of $\hat{x}_j$. Creditors receive the full value of the assets of the bank if the realized value of the assets fall short of the face value. Hence, realized values of debt satisfy

$$\begin{aligned} \hat{x}_1 &= \min\left(a_1\left(\hat{x}\right), \bar{x}_1\right) \\ \hat{x}_2 &= \min\left(a_2\left(\hat{x}\right), \bar{x}_2\right) \\ &\vdots \\ \hat{x}_n &= \min\left(a_n\left(\hat{x}\right), \bar{x}_n\right) \end{aligned} \tag{3.4}$$

where $\hat{x} = (\hat{x}_1, \hat{x}_2, \cdots, \hat{x}_n)$ is the profile of realized values of debt. There is non-decreasing function $F(.)$ that maps realized asset values to the realized asset values that result when debts are settled. The ex post allocation is fixed point of the mapping $F(.)$. Eisenberg and Noe (2001) showed that under mild regularity conditions, there is a unique fixed point of this mapping $F(.)$ (see Shin (2008a) for a simple exposition). Moreover, given the unique fixed point of $F(.)$, the realized value of bank i's debt can be written as a function of the realized repayments from the loans to end-users $\hat{y} = (\hat{y}_1, \cdots, \hat{y}_n)$. Since the realized values $\{\hat{y}_i\}$ are determinstic functions of Y, we can write the realized value of the assets of bank i as a deterministic function of the common factor Y. Hence, we write

$$\hat{a}_i(Y) = \hat{y}_i(Y) + \sum_j \pi_{ji}\hat{x}_j(\hat{y}(Y)) \tag{3.5}$$

Moreover, the comparative statics result on lattices due to Milgrom and Roberts (1994, theorem 3) ensures that the unique fixed point of the mapping $F(.)$ is increasing in the realized repayments $\{\hat{y}_i\}$, so that each $\hat{x}_j(\hat{y})$ is an increasing function of $\hat{y}$ (see Eisenberg and Noe (2001)). In this way, for each bank i, the realized value of its assets $\hat{a}_i$ is a well-defined, increasing function of Y.

3.3. Market Values

Market values are defined as the expected values (seen from date 0) of the possible realized values at date 1 where the expectations is taken with respect to the distribution of loans losses given by the Vasicek model. I use the notation y_i (without any hats or bars) to denote the market value of bank i's loans to end-users. Similarly, x_i is the market value of bank i's debt, given by the expected value of realized debt values $\hat{x}_i$ at date 1. The total marked-to-market value of assets of bank i can then be written as

$$a_i = y_i + \sum_j x_j \pi_{ji} \tag{3.6}$$

The balance sheet identity for bank i in market values is

$$y_i + \sum_j x_j \pi_{ji} = e_i + x_i \tag{3.7}$$

The left hand side is the market value of assets and the right hand side is the market value of the liabilities side of the balance sheet, where e_i denotes the market value of equity of bank i. The matrix of claims and obligations between banks can then be written in market values, as below. The ith row of the matrix can be summed to give the market value of debt of bank i, while the ith column of the matrix can be summed to give the market value of total assets of bank i.

	bank 1	bank 2	$\cdots$	bank n	outside	debt
bank 1	0	x_{12}	$\cdots$	x_{1n}	$x_{1,n+1}$	x_1
bank 2	x_{21}	0		x_{2n}	$x_{2,n+1}$	x_2
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	
bank n	x_{n1}	x_{n2}	$\cdots$	0	$x_{n,n+1}$	x_n
end-user loans	y_1	y_2	$\cdots$	y_n		
total assets	a_1	a_2		a_n		

From the balance sheet identity (3.7), we can express the vector of debt values across the banks as follows, where Π is the $n \times n$ matrix where the (i, j)th entry is π_{ij}.

$$[x_1, \cdots, x_n] = [x_1, \cdots, x_n] \left[\begin{matrix} & & \\ & \Pi & \\ & & \end{matrix} \right] + [y_1, \cdots, y_n] - [e_1, \cdots, e_n] \tag{3.8}$$

or more succinctly as

$$x = x\Pi + y - e \tag{3.9}$$

Equation (3.9) shows the recursive nature of debt in a financial system. Each bank's debt value is increasing in the debt value of other banks. Solving for y,

$$y = e + x\,(I - \Pi)$$

Define the leverage of bank i as the ratio of the market value of assets to the market value of its equity. Denote leverage by λ_i. Then, leverage is defined as

$$\lambda_i \equiv \frac{a_i}{e_i} \tag{3.10}$$

Since $x_i/e_i = \lambda_i - 1$, we have $x = e\,(\Lambda - I)$, where Λ is the diagonal matrix whose ith diagonal entry is λ_i. Thus

$$y = e + e\,(\Lambda - I)\,(I - \Pi) \tag{3.11}$$

Thus, the profile of total lending by the n banks to the end-user borrowers depends on the interaction of three features of the banking system - the distribution of equity e in the banking system, the profile of leverage Λ and the structure of the financial system given by Π. Total lending to end users is increasing in equity and in leverage, as one would expect. More subtle is the role of the financial system, as given by the matrix Π. Define the vector z as

$$z \equiv (I - \Pi)\, u \tag{3.12}$$

where

$$u \equiv \begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}$$

so that $z_i = 1 - \sum_{j=1}^{n} \pi_{ij}$. In other words, z_i is the proportion of bank i's debt held by the outside claimholders - the sector $n+1$. Then, total lending to end-user borrowers $\sum_i y_i$ can be obtained by post-multiplying equation (3.11) by u so that

$$\sum_{i=1}^{n} y_i = \sum_{i=1}^{n} e_i + \sum_{i=1}^{n} e_i z_i \left(\lambda_i - 1\right) \tag{3.13}$$

Equation (3.13) is the balance sheet identity for the financial sector as a whole, where all the claims and obligations between banks have been netted out. The left hand side is the total lending to the end-user borrowers. The first term on the right hand side of (3.13) is the total equity of the banking system, and the second term is the total funding to the banking sector provided by the outside claimholders (note that the second term can be written as $\sum_{i=1}^{n} x_i z_i$). Thus, from equation (3.13) we see the importance of the structure of the financial system for the supply of credit. Ultimately, credit supply to end-users must come either from the equity of the banking system, or the funding provided by non-banks.

3.4. Financial System Leverage

A given degree of leverage for the financial system as a whole is consistent with a wide range of leverage levels for the individual banks. This is true both in terms of the face values of claims, as well as market values. First consider face values. A financial system in face values can be represented as the array $(\bar{e}, \bar{y}, \bar{x}, \Pi)$ that satisfies the balance sheet identity:

$$\bar{x} = \bar{x}\Pi + \bar{y} - \bar{e} \tag{3.14}$$

Then, for positive constant ϕ, we can construct a financial system where the aggregate equity, lending and leverage are all unchanged, but where the debt to equity ratio of all individual banks is ϕ times as large. Specifically, consider the financial system $(\bar{e}', \bar{y}', \bar{x}', \Pi')$ where $\bar{e}' = \bar{e}$, $\bar{x}' = \phi\bar{x}$ and Π' is any matrix of interbank claims whose ith row sum to $1 - z_i/\phi$. Finally, $\bar{y}'$ is defined as

$$\bar{y}' = \bar{e}' + \bar{x}'\left(I - \Pi'\right) \tag{3.15}$$

Then, aggregate lending is given by

$$\begin{aligned}
\sum\nolimits_{i=1}^{n} \bar{y}_i' &= \bar{e}'u + \bar{x}'\left(I - \Pi'\right)u \\
&= \sum\nolimits_{i=1}^{n} \bar{e}_i' + \sum\nolimits_{i=1}^{n} \bar{x}_i' \frac{z_i}{\phi} \\
&= \sum\nolimits_{i=1}^{n} \bar{e}_i + \sum\nolimits_{i=1}^{n} \bar{x}_i z_i \\
&= \sum\nolimits_{i=1}^{n} \bar{y}_i
\end{aligned}$$

Hence, aggregate notional leverage in both financial systems is $\sum_{i=1}^{n} \bar{y}_i / \sum_{i=1}^{n} \bar{e}_i$. However, by construction, the debt to equity ratio of all individual banks is ϕ times larger in the second financial system. The only restriction on the constant ϕ comes from the feature that the ith row of Π' sums to $1 - z_i/\phi$. So, ϕ should not be so small that $1 - z_i/\phi < 0$ for some i. This puts a lower bound on ϕ. But there is no upper bound. We can construct a financial system where aggregate notional leverage is unchanged, but where individual bank notional leverage can be as high as we want. The intuition is that the banks can lend and borrow from each other in large amounts so that their leverage can be raised, without altering the aggregate relationship between the banking sector with the ultimate creditors.

The construction presented above can also be made for the balance sheet quantities expressed in market values, but with one difference. It is still true that two financial systems can have the same aggregate market leverage and where the individual market leverage for the banks differ by a positive factor ϕ. However, for market leverage, the constant factor ϕ cannot be chosen arbitrarily large. This is because the market value of debt x_i cannot be larger than the market value of assets a_i, and the market value of assets is underpinned by the value of fundamental assets $\{y_k\}$. Thus, there is an upper bound in choosing the constant factor ϕ. Subject to this condition, the construction follows the exactly analogous process.

The leverage of the aggregate banking sector itself is related to the leverage of individual banks in the following way. If we denote by L the leverage of the banking sector as a whole, we can write it as

$$\begin{aligned} L &= \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} e_i} \\ &= 1 + \frac{\sum_{i=1}^{n} e_i z_i \left(\lambda_i - 1\right)}{\sum_{i=1}^{n} e_i} \end{aligned} \tag{3.16}$$

where (3.16) follows from (3.13). Thus, other things being equal, the leverage of the banking sector as a whole is increasing in the amount of funding obtained from outside claimholders, as given by the quantities $\{z_i\}$.

Proposition 1. *For any given profile of leverage for individual banks, the leverage of the financial intermediary sector as a whole is increasing in the proportion of funding obtained from creditors outside the financial intermediary sector.*

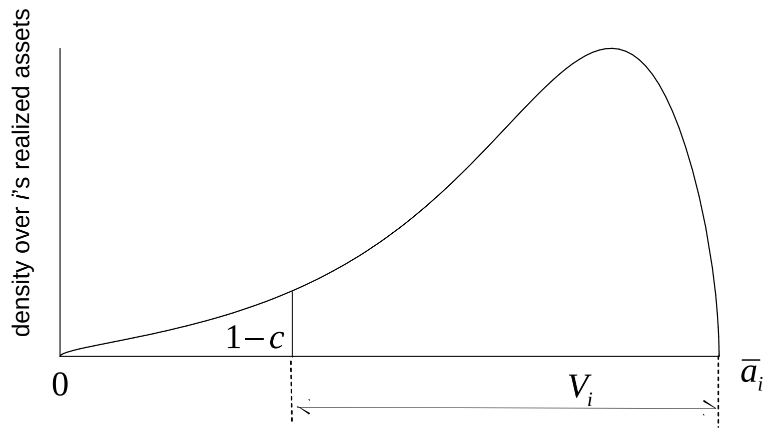

Figure 4.1: Value at Risk

4. Value at Risk

Up to this point, we have confined ourselves to manipulating balance sheet identities. We now turn to the decision rule followed by the banks in order that we can address comparative statics questions on how lending to end-users depends on the underlying parameters that drive credit risk. For this purpose, we employ the notion of value at risk. For bank i its *value at risk* at confidence level c relative to the face value of its assets $\bar{a}_i$, is the smallest non-negative number V_i such that

$$\Pr\left(\hat{a}_i < \bar{a}_i - V_i\right) \leq 1 - c \tag{4.1}$$

Value at risk V_i is the "approximately" worst case loss that can be suffered by the bank, where "approximately worst case" is defined so that anything worse happens with probability smaller than the benchmark $1-c$. The concept of value at risk has been adopted widely, both by the private sector and regulators, and is the bedrock of the capital regulations adopted by Basel regulations. The 1996 Market Risk Amendment of the original 1988 Basel Accord is based on the notion of value at risk, and the Basel II regulations have further built on the notion of value at risk. There is an important open question of how well grounded is the notion of value at risk from a microeconomic perspective. Adrian and Shin (2008b) provide one possible approach in terms of a model of a contracting problem in which value at risk can be shown to arise as part of the optimal contract between a bank and its creditors in a repurchase agreement.

For the exercise here, let us simply assume that banks behave according to the prescriptions that flow from the notion of value at risk and investigate the consequences of such actions. In particular, assume that bank i aims to set market equity e_i to its value at risk V_i, so that

$$e_i = V_i \tag{4.2}$$

4.1. Decrease in default probability

In this context, let us examine consequences of more favorable macroeconomic conditions as reflected the decline of default probabilities $\{p_i\}$ in the Vasicek one-factor model. For simplicity, let $p_i = p$ for all i, and we suppose that p has fallen. Recall that the c.d.f. for realized repayments $\hat{y}_i$ on bank i's loans to end-users is given by

$$\Phi\left(\frac{\Phi^{-1}(p)+\sqrt{1-\rho}\,\Phi^{-1}\left(\frac{z}{\bar{y}_i}\right)}{\sqrt{\rho}}\right) \tag{4.3}$$

Notice that when the default probability p_i for bank i declines, there is a rightward shift in the density over the realized loan values $\hat{y}_i$ in the sense of first degree stochastic dominance. Moreover, since the value of interbank claims are increasing in the aggregate factor Y, a fall in p entails a first-degree stochastic dominance shift in the density over realized values of interbank assets $\sum_{j=1}^{n} \pi_{ji}\hat{x}_j$ held by bank i. Hence, there is a first-degree stochastic dominance shift in the density over bank i's total asset value $\hat{a}_i$. Figure 4.2 illustrates shift. The

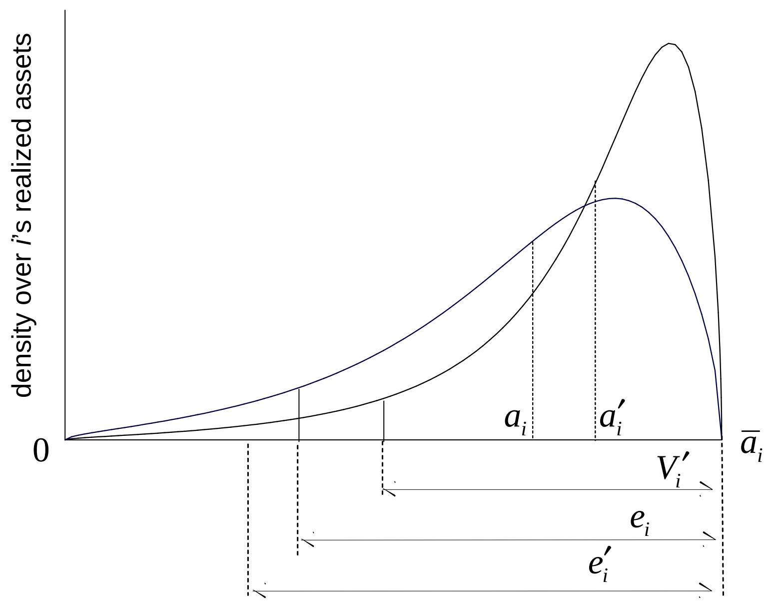

Figure 4.2: Value at Risk and Leverage

market value of assets following the fall in p is given by a_i', and the market equity is given by e_i'. We have $e_i' > e_i$, since the ex post value of equity at the terminal date is increasing in the realized values $\hat{y}_i$, and there is a first-degree stochastic dominance shift in $\hat{y}_i$. At the same time, there is a decline in the value at risk of bank i. This is because the c.d.f. over asset values shifts lower following the fall in p. Therefore, the $(1-c)$-quantile of the realized asset value shifts upward. The value at risk is smaller than before, and is given by V_i'. Thus, following the decline in p, we have

$$e_i' > e_i > V_i' \tag{4.4}$$

so that $e_i' > V_i'$. Hence, bank i has surplus equity in the sense that its market equity is too large relative to the equity that is required to meet its value at risk. The surplus equity could, in principle, be remedied by paying a dividend to shareholders, or by buying back equity by issuing more debt. However, in practice, the evidence points to banks remedying surplus equity by raising the size of total balance sheets instead, rather than paying out the surplus equity.[7] Consistent with this evidence, we assume that if bank i has surplus equity, it expands its balance sheet by increasing the notional value of debt $\bar{x}_i$ and using the proceeds to take on more assets.

Assumption 1. When $e_i' > V_i'$ after the decline in p, bank i increases the face value of its debt $\bar{x}_i$.

As banks raise new debt, they will acquire assets with the proceeds. The interbank claims matrix Π will therefore change. Since our focus here is on the effect on aggregate lending, the exact way in which the interbank claims matrix changes is not of direct interest. Suppose the new interbank claims matrix is given by Π^* after the adjustment of face values, and the profile of market value of debt is given by x^* after the adjust of face values. The comparative statics result due to Milgrom and Roberts (1994, theorem 3) for the fixed point of increasing functions on complete lattices implies that when the face value of bank i's debt increases, the market values of debt is increasing for all banks.[8] Hence, given Assumption 1, we have

$$x_i^* \geq x_i \text{ for all } i \tag{4.5}$$

Let us make one further assumption. As banks increase their borrowing in response to the appearance of surplus equity, they will search for new sources of funding. If financial innovation through securitisation is available, the banks may tap new sources of funding by borrowing from the outside creditor sector - sector $n+1$ in our notation. We therefore make the following assumption.

[7] See Adrian and Shin (2007, 2008b).

[8] See Eisenberg and Noe (2001).

Assumption 2. When banks increase notional debt in response to a fall in p, the proportion of funding raised from the outside creditor sector is non-decreasing.

This assumption places a restriction on the new interbank claims matrix Π^* so that the sum of the i's row of Π^* is no larger than the sum of the i's row of the initial interbank matrix Π. In other words,

$$(I - \Pi^*)\, u \geq (I - \Pi)\, u \tag{4.6}$$

We will see shortly some empirical evidence that bears on Assumption 2.

Proposition 2. When p falls, the value of aggregate lending to end-users increases, both in notional values and in market values.

The argument for this proposition starts with the balance sheet identities before and after the change in face values of debt. The balance sheet identities in face values are

$$\begin{aligned} \bar{y} &= \bar{e} + \bar{x}\,(I - \Pi) \\ \bar{y}^* &= \bar{e}^* + \bar{x}^*\,(I - \Pi^*) \end{aligned} \tag{4.7}$$

where * indicates variables after the change. The face value of equity remains unchanged ($\bar{e}^* = \bar{e}$), so that the change in aggregate notional lending is given by

$$(\bar{y}^* - \bar{y})\, u = (\bar{x}^* - \bar{x})\,(I - \Pi)\, u + \bar{x}^*\,(\Pi - \Pi^*)\, u \tag{4.8}$$

The first term on the right hand side is positive from our assumption that banks react to surplus equity by expanding their balance sheets, while the second term on the right hand side is positive from our assumption (4.6) that an increasing proportion of the funding comes from the outside sector. Thus, $(\bar{y}^* - \bar{y})\, u > 0$, so that total lending to end-user borrowers in terms of notional values increases.

The argument for the increase in the market value of loans to end-users following the decline in p is similar. The balance sheet identities in market values before and after the change are

$$\begin{aligned} y &= e + x\,(I - \Pi) \\ y^* &= e^* + x^*\,(I - \Pi^*) \end{aligned} \tag{4.9}$$

The change in the market value of loans to end-users is

$$(y^* - y)\,u = (e^* - e)\,u + (x^* - x)\,(I - \Pi)\,u + x^*\,(\Pi - \Pi^*)\,u \tag{4.10}$$

Equation (4.10) differs from the analogous one for face values in that the banks' balance sheets now reflect the capital gain on their loan portolio as given by $(e^* - e)\,u$, where $e^* = e'$, where e' is the value given in (4.4). The increased equity is an additional funding source when loans are valued at market values. All three terms on the right hand side of (4.10) are positive, and so $(y^* - y)\,u > 0$.

5. Lending Boom

We can now sketch the scenario for a lending boom by using the results derived so far. The first ingredient is the relationship between the probability of default p on the loan book and the aggregate lending to end-user borrowers, who may be interpreted as being households who borrow in order to buy a house. Proposition 1 gives a declining function that maps p to total lending. Figure 5.1 depicts the negative relationship between total (notional) lending and p, where the total lending appears on the horizontal axis. The arrows indicate that for each level of p, there is an associated level of total lending $\sum_i \bar{y}_i$.

If we further suppose that there is a macroecomic feedback going from total lending to the probability of default, then we may expect amplifications that result

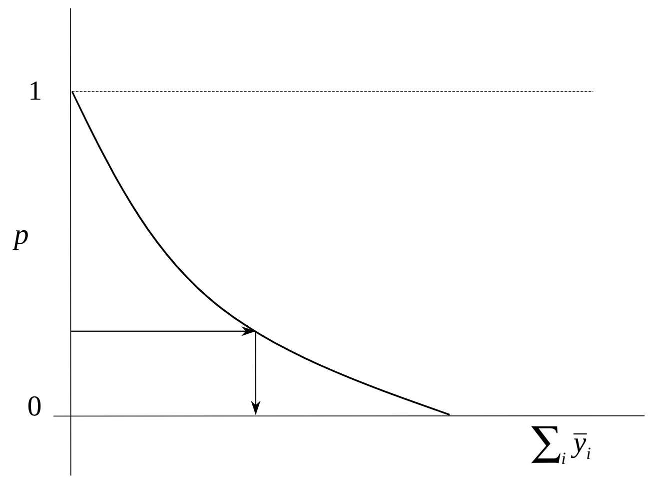

Figure 5.1: Aggregate lending is decreasing in p

from the interplay between strengthening balance sheets and increased lending.[9] If increased loan supply feeds through to more buoyant aggregate conditions, it is possible to sketch a scenario for a lending boom. Thus, for the purpose of illustration, suppose there is a mapping g which maps aggregate lending $\sum_i \bar{y}_i$ to the probability of default p. To be consistent with the interpretation of higher credit supply leading to more buoyant conditions, the function $g(.)$ is should be decreasing. Figure 5.2 superimposes the function $g(.)$ on figure 5.1. Now consider the scenario where the advent of securitisation shifts the mix between internal and external funding that banks use toward greater use of funding from outside creditors. We may interpret this scenario as a decline in the entries of the interbank matrix Π such that the proportion of funding raised from outside creditors increases. As argued in the previous section, such a development increases the aggregate lending to the end-user borrowers even if the leverage of individual

[9]Adrian and Shin (2008c) exhibit evidence that expansions of intermediary balance sheets help explain future growth of GDP components such as housing investment and durable good consumption.

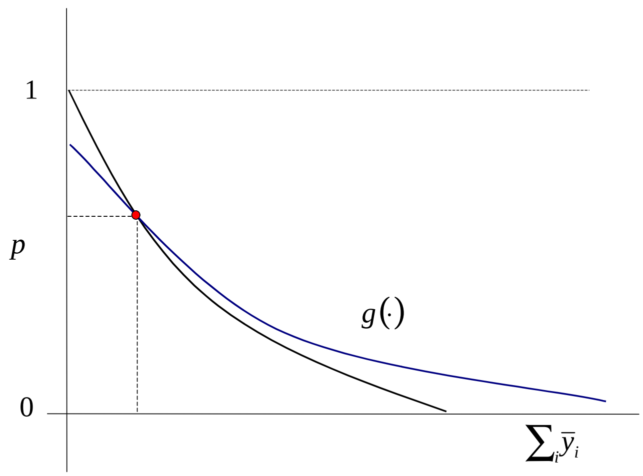

Figure 5.2: Initial point

banks (and their value at risk) is unchanged. In terms of the diagram, the shift to greater use of outside funding can be represented as a shift to the right of the credit supply function. Figure 5.3 depicts the shift in credit supply that results, and the consequences of such a shift. The initial shock from the greater use of outside funding results in a rightward shift in the supply of credit curve. The new intersection point is to the bottom right hand side of the initial point, associated with a lower probability of default p and greater total lending to the end-user sector.

Although there are no explicit dynamics in our framework, it is illuminating to trace out the step-wise adjustment resulting from the one-off shift in use of outside funding. The initial shift is a rightward shift in the credit supply curve which results in higher aggregate lending for a fixed p. However, the macro feedback effect of greater loan supply then kicks in, resulting in a decrease in the probability of default. This adjustment is depicted by the first downward sloping arrow in figure 5.3. However, the fall in p results in greater lending according to

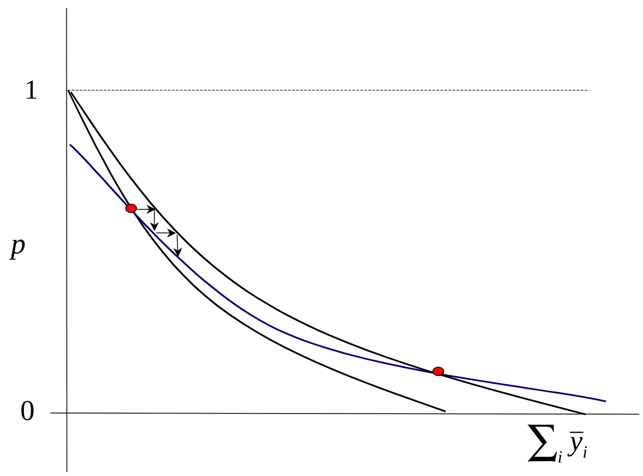

Figure 5.3: Lending boom

the argument for Proposition 1. Greater lending then feeds to lower p, and so on. The new settling point given in figure 5.3 is associated with a substantially lower probability of default as well as a large stock of lending.

5.1. Subprime Lending

At the cost of some additional complexity, it would be possible to incorporate subprime lending into the story. Suppose that the population of prime borrowers is small relative to the expansion of total lending as implied by the new crossing point between the credit supply curve and the macro feedback function $g(.)$ in figure 5.3. Then, once all the prime borrowers have been granted a mortgage, the banking system has to find additional means of creating assets. One way would be for the banks to lend to each other. However, as discussed earlier, the aggregate lending of the banking system to mortgage borrowers must equal the sum of the equity and the borrowing from outside creditors. Since it is the borrowing from the outside creditors which is increasing, the funding must ultimately find its way to an end-user borrower.

Once all the prime borrowers in the population have a mortgage, the banks must find new borrowers in order to expand their balance sheets. The only way they can do this is to lower their lending standards. Subprime borrowers will then start to receive funding. The mechanical nature of our framework in which banks simply choose their balance sheet size masks important questions concerning the short-termist nature of such lending to subprime borrowers. The answer as to why banks would lower their lending standards in order to lend to subprime borrowers must appeal to other frictions within the banking institutions that allows such short-termism. Distorted incentives and shortened decisions horizons induced by agency problems within the bank would be part of the overall story. See Rajan (2005) and Kashyap, Rajan and Stein (2008) for discussion of such incentives.

6. Empirical Evidence

Aggregate lending to end-user borrowers by the banking system must be financed either by the equity in the banking system or by borrowing from creditors outside the banking system. The empirical counterpart to the sector described as the "banking system" is the whole of the leveraged financial sector, which includes the traditional commercial banking system, but also encompasses the market-based financial system that plays a role in extending credit to banks and non-banks by borrowing from outside creditors. In this sense, the leveraged financial sector should be conceived broadly to include all leveraged institutions, such as investment banks, hedge funds and (in the US especially) the government sponsored enterprises (GSEs) such as Fannie Mae and Freddie Mac.

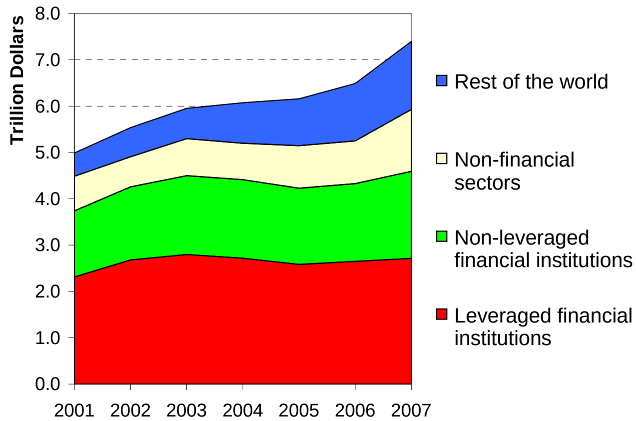

Figure 6.1: Holding of GSE-backed securities (source: US Flow of Funds)

6.1. Evidence from US GSE mortgage-backed securities

A complete disaggregation of the funding source for the leveraged financial sector is not possible due to the lack of detailed breakdowns in the data between funding from leveraged and unleveraged creditors. A partial picture can be obtained, however, by examining the holding of US agency and GSE-backed securities. Figure 6.1 plots the total holding of US agency and GSE-backed securities broken down into the identity of the creditor at the end of each year from 2001 to 2007. The data are from the US Flow of Funds accounts compiled by the Federal Reserve (table L.210). Leveraged financial institutions include commercial banks, broker dealers and other securitisation vehicles. The non-leveraged financial institutions include mutual funds, insurance companies and pension funds. The "non-financial sector" includes household, corporate and government sectors. Finally, the "rest of the world" category indicates foreign creditors, especially foreign central banks or other official sector holders. Figure 6.2 charts the holders by percentage holdings.

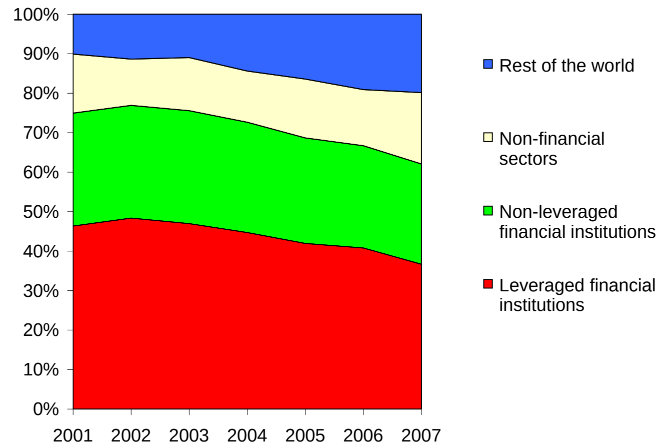

Figure 6.2: Holding of GSE-backed securities (percentages)

The key series for our purposes is the proportion held by other leveraged financial institutions. We see that US leveraged institutions have been holding a declining proportion of the total. At the end of 2002, leveraged financial institutions held 48.4% of the total, but by the end of 2007, that percentage had dropped to 36.7%. There has been a consequent increase in the funding provided by the non-leveraged sector. In terms of the model, this translates to a increase in the z vector of proportions raised from outside the "banking sector" of the model. Notably, the holdings of the "rest of the world" category (which itself is mostly accounted for by foreign central banks) has more than tripled from $504 billion at the end of 2001 to $1,540 billion at the end of 2007. Recall that the increased proportion of the funding coming from outside the banking system plays a key role in the development of the lending boom scenario of the previous section. We see that the assumption has some empirical support.

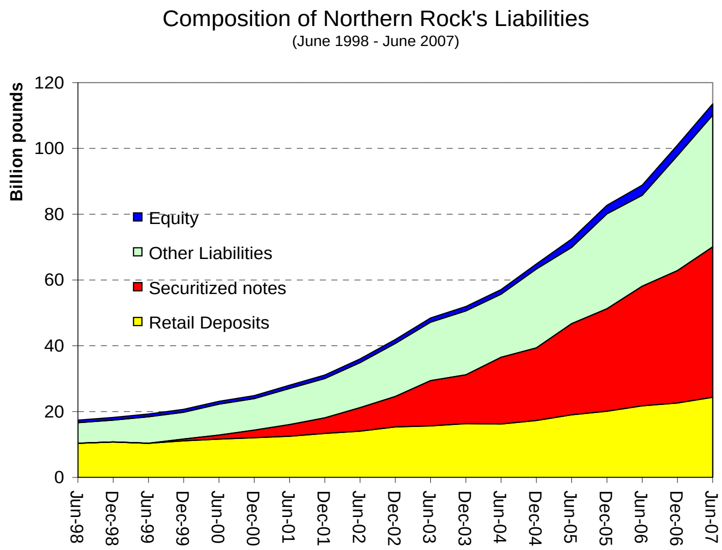

Figure 6.3: Source. Northern Rock annual and interim reports

6.2. Evidence from the UK

The increased importance of securitisation can be found also in the UK, from the balance sheet series of Northern Rock, the UK bank that failed in 2007. Northern Rock was a building society (i.e. a mutually owned savings and mortgage bank) until its decision to go public and float its shares on the stock market in 1997. In the nine years from June 1998 (the first year after demutualisation) to June 2007 (on the eve of its crisis), Northern Rock's total assets grew from 17.4 billion pounds to 113.5 billion pounds (a constant equivalent annual growth rate of 23.2%). By the eve of its crisis, Northern Rock was the fifth largest bank in the UK by mortgage assets. Northern Rock's liabilities reflect both the funding constraints it faced, as well as the way it overcame those constraints. Figure 6.3 charts the composition of Northern Rock's liabilities from June 1998 to June 2007. Traditional deposit funding did not keep pace with total assets, and the gap was made up primarily by securitised notes and other forms of non-retail funding. The "other liabilities" category includes interbank funding, short-term notes and covered bonds. Covered bonds are long-term liabilities written against segregated mortgage assets. The breakdown between leveraged and non-leveraged holders of these liabilities is not available, but two points are worthy of mention. First, the securitised notes were of long maturity, with the maturity being around two years (See Shin (2008b)). Thus, it is quite plausible that a substantial part of such these notes were held by non-leveraged financial institutions. If this is the case, then figure 6.3 would be an illustration of the increased funding obtained from creditors outside the banking sector.

6.3. Liquidity Crisis

The consequences of the increased funding of assets by creditors from outside the banking sector are felt most acutely when the lending boom turns to bust. The framework sketched so far is a static one in which loans are made at date 0 and repaid at date 1. This assumption masks the maturity mismatch that can build up in the aggregate balance sheet when the loans to the end-user borrowers are long-term, while the debt is short term. In the expansion stage, the maturity mismatch does not show up, but the mismatch makes the contraction stage more painful due to the irreversibility of long-term loans. The contraction stage must make reference to more than two dates.

The simplest extension would be to have three dates, 0, 1 and 2, where loans $\{\bar{y}_i\}$ are granted at date 0, and are repaid at date 2 but then banks experience an increase in the probability of default p in the Vasicek credit risk model at date 1. Then, value at risk increases following the parameter shift, while the market value of equity decreases. Indeed, we have the chain of inequalities:

$$e_i' < e_i < V_i' \tag{6.1}$$

which is the mirror image of the inequalities (4.4) that hold during the boom. The counterpart to Assumption 1 would be that the banks attempt to reduce their total balance sheet size by reducing the size of their notional debt level $\bar{x}_i$. However, if the loans to end-users $\bar{y}_i$ are long-term, then banks are not free to reduce the size of their balance sheets flexibly. The constraint on the flexibility will bind harder if the proportion of assets of this type constitute a large fraction of total assets.

In aggregate, the total long-term lending to end-users is mirrored by the size of the funding obtained from lenders from outside the banking sector. Thus, at an aggregate level, the increased use of securitisation is associated with a tighter constraint against rapid reductions in balance sheet size. When value at risk increases, banks must cut back the size of their balance sheets. Some banks will be able to reduce their balance sheets flexibly by not rolling over short-term assets and short-term liabilities. But not every bank can do this, since the financial system as a whole holds long-term illiquid assets financed by short-term liquid liabilities. There will be "pinch points" that are thus exposed when value at risk increases. These pinch point banks will suffer a liquidity crisis.

Northern Rock is a good example of such a pinch point. Its assets were almost all long-term residential mortgages. Thus, it had very little scope to reduce its balance sheet in a flexible way once the crisis struck. Crucially, Northern Rock was vulnerable to the tick-up in value at risk due to its high leverage. Figure 6.4 plots the leverage series from June 1998 to December 2007 according to three different measures of equity. In the early years, there was no distinction between total equity, shareholder equity and common equity. All equity was common equity. However, in 2005, the total equity series included for the first time 736.5 million pounds worth of subordinated debt, as well as 299.3 million pounds worth of reserve notes. Both of these items had been issued much earlier (in 2001), but

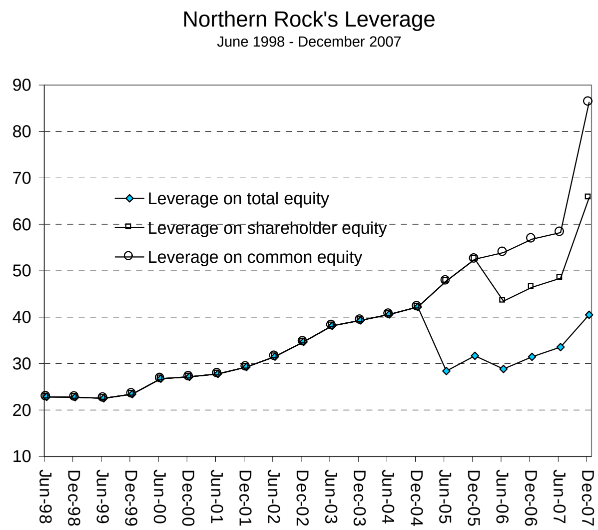

Figure 6.4: Source. Northern Rock annual and interim reports

they were included in the equity series in the annual report for the first time in 2005.[10] The inclusion of these subordinated debt items introduced a jump up in the equity series for Northern Rock, and accounts for the sharp jump down in the leverage series in June 2005 in figure 6.4. However, as we can see also from figure 6.4, when the subordinated debt items are excluded, and equity is construed just as shareholder equity, the leverage series continues to move up in 2005. On the eve of its crisis in 2007, the leverage ratio on common equity stood at almost 60. This made Northern Rock particularly vulnerable among UK banks to the credit crisis that erupted in August 2007.[11]

Although the coventional notion of equity in bank regulation is as a buffer against losses to depositors, the relevant equity measure for funding constraints is

[10]See Shin (2008b).

[11]See Yorulmazer (2008) for an empirical analysis of UK banks at the time of the Northern Rock crisis.

the stake of held by those who control the assets - i.e. the common equity holders. The distinction is seen most clearly for repurchase agreements (repos), where the haircuts applied by creditors determine the permitted leverage (see Adrian and Shin (2008b)). Thus, even though the Basel-style leverage ratios were kept low by issuing subordinated debt and preferred equity, the effective leverage for funding purposes was climbing very rapidly in the case of Northern Rock. Its run in the summer of 2007 should be seen in this context.

7. Related Literature and Conclusions

The importance of securitisation for financial stability lies in the impact of the shadow banking system to affect the total supply of credit to end-users. When there is a decline in the riskiness of fundamental assets (in our case, through a fall in the parameter p), the risk-taking capacity of the shadow banking system increases.

The idea that the changes in the lender's balance sheet is important in determining the supply of credit has also figured in an earlier literature that has emphasized the liquidity structure of the banks' balance sheets (Bernanke and Blinder (1988), Kashyap and Stein (2000)), or the cushioning effect of the banks' regulatory capital (Van den Heuvel (2002)).

The supply-side mechanism for the growth of credit should be distinguished from the larger literature on the fluctuations in credit due to the shifts in the *demand* for credit, as emphasized for instance by Bernanke and Gertler (1989) and Kiyotaki and Moore (1998, 2001). The key to the demand-side explanations of the fluctuation of credit is the changing strength of the borrower's balance sheet and the resulting change in the creditworthiness of the borrower.

The mechanism proposed here is in line with the supply side explanation for the subprime crisis. The greater risk-taking capacity of the shadow banking system leads to an increased demand for new assets to fill the expanding balance sheets, and an increase in leverage. The picture is of an inflating balloon which fills up with new assets. As the balloon expands, the banks search for new assets to fill the balloon. They look for borrowers that they can lend to. However, once they have exhausted all the good borrowers, they need to scour for other borrowers - even subprime ones. The seeds of the subsequent downturn in the credit cycle are thus sown.

According to the picture painted here, the subprime crisis has its origin in the increased supply of loans - or equivalently, in the increased appetite for new assets to fill up the expanding balance sheets. In this way, it is possible to explain two features of the subprime crisis - first, why apparently sophisticated financial intermediaries continued to lend to borrowers of dubious creditworthiness, and second, why such sophisticated financial intermediaries held the bad loans on their own balance sheets, rather than passing them on to other unsuspecting investors. Both facts are explained by the imperative to expand balance sheets during an upturn in the credit cycle.

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