Balance Sheet Adjustments in the 2008 Crisis

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We measure how securitized assets, including mortgage-backed securities and other asset-backed securities, have shifted across financial institutions over this crisis and how the availability of financing has accommodated such shifts. Sectors dependent on repo financing – in particular, the hedge fund and broker-dealer sector – have reduced asset holdings, while the commercial banking sector, which has had access to more stable funding sources, has increased asset holdings. The banking sector also increased its leverage dramatically over this crisis. These findings are important to understand the role played by the government during the crisis as well as to understand the factors determining asset prices and liquidity during the crisis.

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1. Introduction

We have seen a massive restructuring of financial sector balance sheets since late 2007 and will likely continue to do so over the next year(s). The impetus for this restructuring has been deteriorating financing conditions in debt and equity markets in 2007/2008 as well as the loss of liquidity in the secondary markets for many assets.

The first objective of this paper is to present a set of facts on the financial sector's balance-sheet adjustments over the period from the fourth quarter of 2007 to the first quarter of 2009. This time frame includes the most dramatic episode of the financial crisis in the fall of 2008. We document how assets and financing have shifted across different private and public segments of the financial sector.

Examining the data on balance sheet adjustments is important because they help shed light on theory. The most common theoretical references in understanding the crisis are models in which the asset trading decisions of the financial intermediary sector are directly affected by the financing available to these intermediaries.[2] However, while there is truth in each of the many theoretical mechanisms that have been proposed, it is important to step back and see how these mechanisms fit together and which of the mechanisms may have played a larger or smaller role during the crisis. We attempt to do this by offering a birds-eye view of the crisis. After presenting the data, the last section of our paper turns to an evaluation of different financial crisis theories.

To provide one instance of why these are worthwhile objectives, consider the "deleveraging" phenomenon which has been widely discussed by both policymakers and academics (see, for example, Adrian and Shin, 2009, and Brunnermeier, 2009). Haircuts in the repo market (i.e., the market for security loans) rose dramatically during the crisis. Table 5 illustrates the rise over a period from 2007 to 2009. The higher haircuts reflect a tightening of credit conditions. For a hedge fund that is financing asset holdings in the repo market, mechanically, a rise in haircuts that is not offset by either slack in the existing equity capital base or an infusion of fresh equity capital will cause the fund to liquidate assets. That is, the rise in haircuts will force the hedge fund to reduce its leverage and asset holdings. This deleveraging process has occurred in many parts of the financial system and is consistent with the theoretical analyses of Geanokoplos and Fostel (2008), Adrian and Shin (2009), and Brunnermeier and Pedersen (2009) which model constraints on the ability of intermediaries to take on leverage through loans (i.e. margin or leverage constraints).

[2] A non-exhaustive list includes Gromb and Vayanos (2002), Allen and Gale (2005), Geanokoplos and Fostel (2008), He and Krishnamurthy (2008, 2009), Adrian and Shin (2009), and Brunnermeier and Pedersen (2009).

However, as we document, there is much more nuance to deleveraging than is commonly appreciated. We find that while the hedge fund and broker/dealer sector reduces holdings of securitized assets (mortgage and other asset-backed securities) by approximately $800bn, the commercial banking sector increases its holdings by close to $550bn. Moreover, under fairly modest estimates of the discrepancy between reported and true losses for the banking sector, the leverage of the commercial banking sector rises from 10 to between 20 and 32 over the period we study. The leverage of the banking sector is much higher than normal during the crisis. Thus, we find that the crisis involves a change in the distribution of leverage across the intermediary sector, rather than an absolute change in leverage uniformly across the economy.

This finding implies that the deleveraging theories of crises are correct in part, but not in whole. A fuller theory of leverage adjustments in a crisis also needs to account for where the assets sold by deleveraging sectors end up and how acquirers finance these acquisitions. Our data suggests that the assets sold end up on the balance sheets of the commercial banking sector and the government. Moreover, the banking sector financed the asset growth by issuing debt that was guaranteed by the government. Thus, we argue that a fuller theory of the crisis should model the asset trading decisions of the commercial banking sector, which has not been leverage-constrained but has faced equity capital constraints. We discuss such theories in the conclusion.

The bulk of this paper is concerned with estimating changes in the holdings of securitized assets across different segments of the financial sector. We also document changes in the holdings of the Federal Reserve and the GSEs. Finally, we document changes in some of the key liabilities of the financial sector. The estimates are made by drawing on a variety of data sources, including SEC filings, FDIC call reports, some hedge fund databases, and the Federal Reserve Flow of Funds.

It is important to emphasize that data limitations induce considerable uncertainty in many of our estimates. While we believe there is a consistent pattern that emerges from the data, we necessarily have to make a number of educated guesses along the way. Reading through the next sections will provide a sense of the measurement error involved in our computations. In most places, we provide sensitivity analyses for the computations. Our baseline findings are as follows. First, on the asset side we find that:

i. Hedge funds and broker/dealers reduce holdings of securitized assets by approximately $800bn.
ii. Insurance companies reduce holdings by approximately $50bn.
iii. Commercial banks increase holdings of securitized assets by approximately $550bn
iv. The government (including the Federal Reserve and the GSEs) increase holdings by approximately $350bn.

Second, on the liability side, and in particular the short-term money markets, we find that:

i. Repo finance shrinks by approximately $1.5tn.
ii. Government-backed debt issued by the commercial banking sector, including FDIC insured deposits, and FDIC guaranteed bonds, increases by approximately $1.3tn.
iii. Book leverage of the commercial banking sector increases from 10 to between 20 and 32.

The next two sections of the paper offer details on these computations. Sections 4 and 5 detail changes in asset holdings of the private sector. Section 6 details the interventions of the government in the banking sector. Section 7 presents data on changes in the financing to the intermediary sector. Section 8 takes stock of the data and evaluates different proposed crisis theories in light of our empirical findings, where we discuss leverage-constrained theories and equity risk-capital theories. The paper includes a data appendix that provides further detail on data sources and computations.

2. Markets and Institutions

a. Mortgage and Credit Markets

Table 1 lists the type of asset markets that are the focus of this study. The table covers the securitized debt markets for mortgage and credit assets. We are interested in understanding how the securities in Table 1 have been bought and sold across the financial marketplace. Falling real estate prices, combined with declining corporate profitability and household income, have contributed to losses on all of these assets (see Table 3 for estimates of losses).

The typical security is an asset that is backed by a pool of loans originated by some financial institution, but has subsequently been sold by the financial institution and is being held by another entity. Table 1 reports nearly $9tn of mortgage-backed securities (MBS), where the backing is a pool of residential loans. This category is further subdivided into agency GSE and non-agency. The GSE backed mortgage pools are insured by a government agency and are therefore the lowest risk mortgage-backed securities. There are just over $6tn of this class of mortgage-backed securities. At the other end of the spectrum, the ABS CDOs are among the most risky of the securities. These securities pool risky tranches from other asset-backed securitizations and further tranche them into asset-backed securities. While there are only $400bn of these securities, the losses and liquidity problems are most pronounced in this category.

The corporate bond category includes high-grade corporate bonds that have not been much affected by this crisis. It also includes asset-backed commercial paper (ABCP) which has also played an important role in the crisis (see Acharya, Schnabl, and Suarez, 2009). The dynamic in the ABCP market is a microcosm of the deleveraging in the financial markets. In this crisis, investors reduced their willingness to provide credit to ABCP. As a result, the amount of outstanding ABCP has shrunk by nearly $650bn. In most cases, commercial banks have absorbed the assets/loans underlying ABCP (see Section 4.e for details.)

In addition to the securities listed in Table 1, it is worth noting that there is nearly $12tn of loans that are being held by the financial sector. These loans have also contributed to some of the losses suffered by the financial sector and have affected the behavior of banks. We restrict attention to securities in our analysis because of data availability. However, it would be informative to have further detail on the loan portfolios of banks.

The total in Table 1 is just over $17.5tn of assets. Our analysis focuses on a large asset class that has been subject to a shock due to falling real estate prices and household income. This is important to keep in mind because there are also significant measurement issues we encounter. We think that since our study focuses on a large quantity of assets, the measurement problems will not invalidate our conclusions. If on the other hand, our study documented changes in the holdings for a small class of assets (e.g. convertible bonds) it is likely that the measurement issues would be insurmountable.

b. Financial Institutions and Losses

The debt instruments in Table 1 are held by a number of financial institutions. Table 2 provides a sense of the main financial institutions in the U.S., and the size of these institutions as measured by total assets. We focus on five major categories of asset holders: commercial banks, broker/dealers, hedge funds, GSEs, and insurance companies.

Table 3 gives a breakdown of the write-downs and losses suffered, by financial sector, from the start of the crisis in 2007 to March 2009. These losses are reported by the firms and may not be indicative of the true extent of losses. For example, while the US commercial banking sector reports losses of $500bn, the IMF in its Global Financial Stability Report of April 2009 estimates that total losses of this sector will exceed $1.6tn. More generally, it is likely that true losses exceed the numbers in Table 3. However, as we explain in the next section, the mismarks will not appreciably change our results.

3. Methodology

Our aim is to understand how assets have shifted across the financial system and the role of external financing in supporting this restructuring. We examine the main holders of assets from Table 2, and try to estimate purchases/sales of mortgage and credit assets.

Suppose that at date t we can compute the total mortgage and credit assets held by a sector as A_t. Moreover, suppose that we can measure the repayment/maturity rate of these assets during the period between date t and date t+1, net of the new issuance rate, as *f* (as a fraction of date t holding A_t). Then, as an accounting identity:

$$A_{t+1} - A_t (1- f) = \text{Purchases} - \text{Losses} \qquad \text{(eq. 1)}$$

Since we observe A_{t+1} and A_t from publicly available data sources and we can measure losses from Table 3, we can estimate the purchases made by a given sector, with an assumption on *f.*

Based on Bloomberg,[3] we use an *f* of 7% in the computations that we detail in the next section. We also report computations for *f* =12% in order to gauge the sensitivity of our analysis to the net repayment rate.

We report the purchase numbers for each sector by measuring the change from Q4 2007 to Q1 2009. This time period spans 2008 which is the period with greatest balance sheet adjustment. It stops just before the improvement in market conditions which began in April 2009.

We roughly check whether the sum of purchases across sectors is zero, as would be implied by market clearing. We cannot overemphasize however the roughness of this computation. There are serious measurement issues that we run into in our exercise. While we feel comfortable on the coarse magnitudes of our results, they are not so precise that the sum will be zero.

Here are some of the main measurement issues that we potentially face. Some issues are more critical than others for our methodology, and we try our best to address them accordingly.

1. For a precise computation, the assets under consideration in (eq 1) should be the same asset. That is, the requirement that the sum of purchases equals to zero applies to a single class of mortgage-backed securities. In our analysis, we group a large class of mortgage and credit assets together, which creates measurement errors in our estimates. We do this because financial institutions group different sets of assets under different headings in their reporting and there is not a single break-down of assets that

[3] Bloomberg reports the aggregate repayment rate of 17% across a large (>$3tn) sample of ABS and MBS in the year 2008 (see Bloomberg CMO/ABS Market Profile; function *mtge CAMP*). They also report that the aggregate rate of new issuance is 10%. These numbers lead to our choice of 7% as a net repayment rate.

can be applied uniformly across different institutions' reports. On the other hand, as suggested in Tables 1, 2, and 3, the numbers involved in our computation are in the order of trillions of dollars. Therefore, it is plausible that even the rough measures that we perform are interesting and informative.

2. There is widespread concern among many observers that assets on financial institutions' balance sheets are not appropriately marked to true values (e.g., Vyas, 2010). Suppose that banks mark their books at t+1 at $100 too high a value and also report losses that are $100 too small. Then, note that eq. 1 will imply that,

   $100 + A_{t+1} - A_t(1 - f) = \text{Purchases} - (\text{Losses} - 100)$.

   Importantly, the $100 mismark cancels out in calculating the purchase amount. This observation implies that as long as the book mark and the reported losses apply to the same set of assets, our computation will not be affected by this issue. In practice, there may be cases where the latter caveat does not apply, but this logic does suggest that the mark-to-market problem which may be severe in practice is much less severe for our exercise.

3. There are double counting issues that affect our computations and may lead the sum of purchases across sectors to differ from zero. Here is a typical example: Suppose that a bank initially owns $100 of an MBS. Suppose that the bank makes a $100 repo loan to a hedge fund that uses the $100 to buy the MBS from the bank. Now the bank has an asset (repo loan) of $100, and the hedge fund has an asset (MBS) of $100. Total assets across the bank and hedge fund are $200. Now suppose that we hit a crisis state where the hedge fund goes out of business and is forced to sell the MBS back to the bank. Now, we will measure hedge fund assets to fall by $100. If we include the repo loan in measuring total bank assets, then the total bank assets (MBS + Repo Loan) remain the same. In this case, we measure asset sales of $100 by the hedge fund and no increase in assets by the bank. That is the same as stating that the trade across the bank and the hedge fund is -$100. The problem arises because the repo loan is an asset of the bank and liability of the hedge fund. If we focused only on the change in holdings of the MBS, we would find that the hedge fund reduces holdings by $100 of MBS and the bank increased its holdings by $100 of MBS. To minimize this double counting problem we try to only measure holdings of asset-backed securities on balance sheets in computing A_t. In particular, we ignore loans or repo in our asset measure. By doing so, we avoid this double-counting problem although we probably also throw out economically interesting assets that are classified as loans. When we apply these two rules, taking the example,

we would only see that MBS rises by $100 in the bank, and MBS drops by $100 in the hedge fund.

4. Purchases/Sales

In this section we calculate the purchases/sales of credit and mortgage related assets across different financial sectors: Hedge funds, brokers/dealers, insurance companies, and finally commercial banks.

a. Hedge Funds

Table 4 lists the equity capital (or what the industry refers to as assets under management, AUM) of the hedge fund sector by various investment strategies over the current financial crisis. The source for this data is the Hedge Fund Flow Report by Barclay Hedge (2008, 2009). Total capital falls by $1tn over the relevant period, due both to trading losses and redemptions. We estimate that the breakdown between trading losses and redemptions is 66.3% and 33.7%.[4] For more detailed data description, see Appendix.

We are interested in a measure of credit and mortgage related assets held at Q4 2007 and Q1 2009. To this end, we need to know which of the strategies comprise the credit/mortgage assets. This determination is the most serious source of error in our computation. With any alternative we are likely mixing in other assets, such as corporate or U.S. Treasury bonds, with the assets of interest. We present results for three alternatives: 1) only fixed income, 2) fixed income and macro, and 3) a broad class which includes distressed securities, fixed income, and macro as well as a fraction of the multi-strategy and sector specific funds' capital.

Second, we need leverage information at Q4 2007 and Q1 2009, as we will multiply the capital devoted to a given strategy by the leverage of that strategy and aggregate across strategies to come up with three different measures of asset holdings. The Q4 2007 leverage is based on TASS hedge fund database which provides measures of leverage across different strategies as of 2006. For example, the leverage ratio of the fixed income strategy is 4.5, indicating that in our first scenario the total credit and mortgage related assets held by the hedge fund sector in Q4 2007 is roughly $720bn.

[4] This estimate is based on the surviving funds, which lost $161bn by redemption and lost $317bn from asset trading. Data source: Hedge Fund Flow Report by Barclay Hedge (2008, 2009).

For the leverage ratio in Q1 2009, we do not have a detailed breakdown of leverage at that time. Rather, we use Lo (2008) which reports that the hedge fund industry average leverage for all of 2008 was 2.3. Of course, credit markets tightened considerably toward the end of 2008. Table 5 reports how repo haircuts have evolved over the crisis. The haircuts on AAA rated Collateralized Mortgage Obligations went from 10% in 2007 to 30% in early 2008 to 40% in early 2009. The increase of haircuts through 2008 into 2009 should be expected to decrease leverage even further. To reflect this rise in haircuts, in Appendix we calculate the 2008 year-end leverage to be 1.7 to match two facts: 1) The average leverage ratio over the year 2008 is 2.3, and 2) This average leverage reflects variation in haircuts whereby haircuts double over the year 2008. We then use 1.7 as the Q1 2009 leverage measure for all of the different strategies.

Now we are ready to apply (eq.1) to compute the sale estimates from hedge fund sector, which is detailed in Appendix. The results are: a lower bound sale estimate of $492bn (fixed income only), a medium estimate of $546bn (fixed income and macro) and an upper bound of $754bn (wide class).

b. Brokers and Dealers

Table 6 provides data on the main brokers and dealers in the US as of December 2007. Trading assets held by these entities totaled near $2.6tn. We analyze in further detail the behavior of three of these firms: Goldman Sachs, Merrill Lynch, and Morgan Stanley. We restrict attention to these three firms not only because of data availability issues, but also because these three are "pure" broker/dealers through most of the period.[5]

Our strategy is to estimate asset changes from the SEC filings of these three firms and then assume that they are representative so that we can infer the behavior of other players in this industry.[6] The most serious guess in our estimate arises in the representativeness assumption. Thus we offer three alternative scenarios: the lower (medium, upper) bound based on the smallest (average, largest) percentage change in asset holdings across the three firms.

[5] Many of the other entities in Table 6 are owned by a bank holding company so that their balance sheet adjustments may have been influenced by the holding company with significant commercial banking operations such as Citigroup or JP Morgan Chase. Goldman Sachs and Morgan Stanley do become bank holding companies in the fall of 2008, so that there is a limit to how clean our pure broker/dealer measure can be. However, it is worth noting that even after converting to holding company status, commercial banking operation still represents a very small fraction of these entities and their main business remains to be in the broker/dealer industry. Separately, Merrill Lynch ceased to be a stand-alone broker/dealer and became part of the Bank of America as of January 2009. However, we do not observe major changes in Merrill Lynch's asset holdings in the first quarter of 2009.

[6] The flow of funds of the Federal Reserve is another data source for understanding the change in the broker/dealer sector. While our computations result in a similar picture as painted by the flow of funds, the advantage of our computations is that the SEC filings allow a more detailed breakdown of asset holdings than is provided in the flow of funds.

Table 7 reports the trading assets for the three firms in November 2007, February 2008 and March 2009. We compute the trading and mortgage related assets by summing reported holdings of Agency and non-Agency mortgage-backed securities, asset-backed securities, and credit market securities. Finally, note that the trading asset account is treated as fair-value mark-to-market accounting. For detailed data construction, see Appendix.

The fall in credit and mortgage assets across the three firms in Table 7 from November 2007 to March 2009 is $181bn. As a fraction of initial total trading assets, this fall is 15.8%. Across the three firms, the smallest percentage fall is 11.7% (Goldman Sachs), while the largest is 20.0% (Merrill Lynch). We apply these numbers to the rest of broker/dealer sector, which is holding trading assets of $1456bn at the end of 2007. Based on (eq.1), and noting that the broker/dealers have lost $100bn on mortgage/credit assets, we find net sale estimates for the three scenarios as $205bn, $254bn, and $307bn. [7]

c. Insurance Companies

Table 8 gives data on the insurance sector, which is another important holder of credit and mortgage related assets. We choose the eight largest insurance companies and examine their holdings of mortgage and other ABS positions, as reported on their SEC filings. These eight insurance companies have a total asset size of $2,136bn as of Q4 2007, which accounts for about 34% of the insurance sector. The mortgage holdings include both Agency and non-Agency MBS.

The fall in holdings including AIG is $172 bn. If we exclude AIG, the fall is $33bn. AIG in some sense is not the typical insurance company, and as events have revealed, had a business model with elements of a broker/dealer.

We assume that these eight insurance companies are representative and extrapolate to the rest of the insurance sector to compute the aggregate change in holdings. The representativeness assumption is the principal source of error in this computation. We provide three scenarios. Our upper bound scenario assumes that all eight insurance companies, including AIG, are representative. Our medium scenario assumes that seven insurance companies, but excluding AIG, are representative of the rest of the sector. Our lower bound

[7] There is another consideration that affects the interpretation of our computations in this section. We do not have information on derivatives positions. Thus, it is possible that some of these assets are hedged by derivatives so that the broker/dealers have a small exposure to the underlying asset risk. Nevertheless, our computation of asset sale is still correct, and we just have to modify our interpretation that the broker/dealers are unwinding positions as opposed to selling off risk.

scenario assumes that rest of the insurance sector behaves like the three firms in Table 8 that have the lowest rates of asset shrinkage.

The growth rates for each scenario, measured as change in securitized asset holdings as a percentage of total initial assets, are -9.7%, -3.5%, and -0.8%. We then scale the rest of the sector in each of three scenarios discussed above, and our three estimates of asset sales are $247bn, $50bn, and $-36bn (see Appendix for details.)

d. Commercial banks

Table 9 provides data on the changes in the asset side of commercial bank's balance sheet from 2007 to 2009. The data is from the Flow of Funds of the Federal Reserve. Note that this data is backfilled to reflect the effect of mergers and there was a significant amount of bank merger activity in 2008. Also, we exclude the data for bank holding companies, i.e. the data is L109 minus L112. The largest part of the assets of holding companies is equity in a commercial bank, and including the holding company data would create unwanted double counting. Including the holding companies does not alter our findings.

Unlike the other balance sheets we have examined, the commercial bank balance sheets grow by close to $1.7tn (11.1tn minus 9.4tn). This is despite losses of $500bn, suggesting that the banking sector has accumulated assets, in contrast to the rest of the financial sector.

Table 10 presents in further detail the changes in holdings of mortgage and asset-backed securities from Q4 2007 to Q1 2009, broken down by the type of banking institution. The Agency and GSE-backed holdings of MBS clearly increase across most categories. The holdings of ABS in U.S. commercial banks increase, while the holdings of private MBS fall slightly. The ABS holdings are from FDIC data. We are unable to see the detailed holdings of private MBS and ABS for the other institutions from the flow of funds.

Based on Table 10, we provide three estimates of the asset growth by the banking sector. The FDIC call reports and flow of funds data allow us a fairly accurate read on holdings of securitized assets, in contrast to the data problems in other computations. However, we still require an estimate of losses on security holdings to compute the net purchase/sale. The loss estimates are the only serious source of error in the banking computation.

The banking sector has reported write downs and losses on mortgage-related holdings of $500bn, but these include losses on mortgage loans as well as securities. For our computation,

we need a narrower measure of losses on the security portfolio. We consider three scenarios (see detailed data and calculation in Appendix):

1. The upper bound scenario is based on assigning total losses of $500bn to the sector.
2. Our median scenario is based on assigning a fraction of the losses to the security portfolio. We use the estimate of the IMF Global Financial Stability report of April 2009 which gives a breakdown of the losses between security holdings and loan holdings, and the estimated loss for the security holdings is $313bn.
3. Finally, our lower bound scenario is based on assumptions about loss rates on the specific assets in banks' portfolios. We use the IMF Global Financial Stability Report of October 2008 which gives the loss estimates of specific toxic assets, and the total loss estimate is $176bn.

Given these loss estimates, we use (eq.1) to arrive at the following estimates for the net asset **purchase** by the banking sector: The upper bound estimate is $731bn, the medium estimate is $544bn, and the low estimate is $407bn.

e. Banking Growth

The preceding data show that the banking sector grew, while other sectors shrank. It would be interesting to pinpoint causality and in particular to show that the banking sector acquired the assets sold by the other sectors. However, we do not have any data to clarify this point. Figure 1 is weak evidence consistent with this hypothesis. The MBS holdings of the banking sector are graphed, by quarter. Holdings rise in the second and fourth quarter of 2008, at times when the rest of the financial sector is in turmoil, suggesting that some of the growth in banking assets may be due to shedding of assets in other financial sectors.

Regardless, one conclusion we can reach is that the banking sector has behaved differently than other sectors, and in particular, is less constrained in acquiring assets. This section offers three specific instances of asset acquisitions, which provide further evidence that the banking sector has faced different constraints than the rest of the financial sector.

First, consider that Merrill Lynch and Bear Stearns were acquired by commercial banks in 2008. In both deals, the commercial bank acquired a large asset portfolio. It also acquired the liabilities of the broker/dealer. That is, it acquired a fairly risky asset position whose deterioration could have compromised the viability of the commercial bank. We know that the government was involved in both of these cases, but not to the extent that the banks were insulated from risk.[8]

[8] Washington Mutual and Countrywide were also acquired by commercial banks in 2008. One point worth noting is that, because the Flow of Funds data is back-filled to reflect the effect of these mergers, Table 10 and Figure 1 are

Second, consider the growth of JP Morgan Chase bank's available-for-sale (AFS) securities over the period from 9/30/2008 to 3/31/2009. There are no significant acquisitions during this period, making it a fairly clean period to examine. Both the Bear Stearns and Washington Mutual acquisitions occur prior to 9/30/2008. The data on the AFS securities are from JP Morgan's SEC quarterly and annual reports which contain a more detailed break-down than the FDIC call reports.[9] The total AFS securities grow from $206bn to $334bn from Q3 2008 to Q1 2009, despite the fact that this is a period of unprecedented turmoil in financial markets. Within the AFS securities, the largest increase occurs in Agency MBS, which accounts for $72bn of the increase in AFS securities (rising from $127bn to $199bn). The value of non-Agency MBS remains close to unchanged (at $13bn). Given losses and some repayment on these securities, it is likely that the holdings of non-Agency MBS also rose over this period. Holdings of ABS rise from $23bn to $31bn over this period, indicating significant purchases of ABS. The largest rise is in credit card ABS. Together this data suggests that JP Morgan Chase was a significant buyer of securitized assets at a time that many other parts of the financial sector were shrinking.

Last, consider the deleveraging in the ABCP market. As detailed by Acharya, Schnabl, and Suarez (2009), the commercial banking sector had provided an explicit or implicit liquidity guarantee on nearly $1.25tn of ABCP as of August 2007. This amount includes the SIVs where the banks had offered only implicit guarantees. The outstanding amount of ABCP shrinks to $833bn by December 2007 and $650bn by the end of 2008, with ABCP investors exiting their investments. Acharya, Schnabl, and Suarez report that these investors only lost 1.7% on the ABCP. This finding suggests that the bulk of the underlying assets were absorbed onto bank portfolios. If banks indeed kept the assets that they acquired through the liquidation of ABCP conduits, rather than consequently selling the assets, then this factor could lead to a rise in bank MBS assets. It is unclear if banks indeed kept the assets or sold them and to what extent the liquidation of ABCP drove asset growth in 2008.[10] However, the key point to takeaway is that, if this factor drove the rise in bank assets, then banks made a choice to keep the assets rather than sell the assets, as likely would have happened if the liquidity guarantor was a

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free of the data issue caused by these M&A activities. On the other hand, there may be a slow change in assets in the case of the broker/dealer acquisitions. Take for example, the JP Morgan Chase acquisition of Bear Stearns. Any MBS assets acquired in this merger will, at the time of the merger, be held in JP Morgan Chase's broker/dealer rather than the commercial bank. Thus the merger will not cause an immediate raise in commercial banking assets as computed from the call reports. However, suppose that over time, the securities held by Bear Stearns are transferred to JP Morgan Chase's commercial bank (perhaps because they can be financed more easily that way), then we would see a slow rise in banking assets.

[9] The growth in AFS securities we document reflects growth in the holdings of JP Morgan Chase commercial bank and not the broker/dealer owned by the holding company. We can see this by comparing the AFS values reported in SEC filings to holdings data from call reports. The numbers are almost identical.

[10] Note that ABCP outstanding shrinks from $1.25tn to $833bn by December 2007. This suggests that the bulk of ABCP liquidation occurs in 2007 and not during 2008, and thus is likely not responsible for the 2008 asset growth at banks.

broker/dealer or hedge fund. That is, regardless of whether banks growth is due to ABCP liquidation or not, this phenomenon suggests the existence of different constraints faced by the banking sector, in comparison to the rest of the financial sector. [11]

f. Foreign Investors

Table 11 provides data on foreign holdings of asset backed securities. The data is from the U.S. Treasury Report on Foreign Portfolio Holdings of U.S. Securities. Unfortunately the data does not allow for a sampling at Q1 2009 and only allows for samplings in Q2 (June 30) of each year.

If we measure from Q2 2007 to Q2 2009, the total increase in holdings of Agency MBS is $182bn while the non-Agency MBS and ABS holdings decline by $96bn. It is worth noting that the bulk of the change is in the foreign official holders' positions in Agency MBS, which increases by $239bn. We do not have data on the reported losses on these securities to compute an accurate net trade by foreign investors. However, we can do a back-of-the-envelope calculation proceeding as we have for the lower bound scenario for commercial banks by making assumptions on how much the values of the underlying assets change over this period. In our banking scenario, we assume that Agency MBS falls in value by 5% and the non-Agency securities fall in value by 25% until Q1 2009. From Q1 2009 to Q2 2009, the spreads in most asset-backed securities fell substantially. For example, the spreads on 30-year GNMA MBS fell from 1% to 0.5% over this period (see Krishnamurthy, 2010, Figure 9). Thus it is appropriate to use lower loss estimates. We assume that Agency MBS do not suffer losses over this period and that non-Agency securities decline by 15%. Based on the 7% repayment scenario, we find that Agency holdings increase by $262bn while non-Agency holdings increase by $46bn, for a total increase of $308bn.

The increase of $308bn is not directly comparable to our other estimates because the measurement period starts 6 months prior and ends 3 months later. The data in Table 11 suggests that much of the increase in Agency MBS holdings occurred between Q2 2007 and Q2 2008 and not during the crisis period of the fall of 2008. Thus it is likely that the $308bn figure is an overestimate. The Federal Reserve Flow of Funds (L107) indicates foreign investors' holdings of Agency MBS debt and Agency own-debt (i.e. non MBS) increases by 5.1% (or $67bn) over the period from Q2 2007 to Q4 2007. If we assume that the holdings in our measured Treasury data also increase by 5.1% over the Q2 2007 to Q4 2007 period, then we estimate that the increase in holdings from Q4 2007 to Q2 2009 is $248bn.

[11] Ivashina and Scharfstein (2009) discuss another source of growth in bank assets. They document that many firms draw down credit lines during the turmoil of the fall of 2008, causing bank loans to rise. They stress that these loan increases are "involuntary" rather than voluntary. In the ABCP liquidations, banks involuntarily take on ABCP assets, but there decision to hold on to these assets is voluntary.

The U.S. Treasury Report on Gross & Net Total Foreign Purchases of Asset-Backed Securities provides direct estimates of foreign purchase of MBS and ABS. This data, which would be ideal for our computations, unfortunately does not begin until March 2009. The data is still useful for us because it indicates how much of the total increase of $308bn was due to purchases from March 2009 to June 2009. The report indicates that Agency MBS purchases totaled $31bn while non-Agency MBS and ABS sales totaled $14bn. Thus, on net, the increase in holdings from Q4 2007 to Q1 2009 totals $204bn.

These estimates are much more uncertain than our previous ones. As a result, we do not think it is appropriate to emphasize the $204bn figure. Moreover, one problem with this data is that it describes the winding down of an asset-backed conduit, say located in the Cayman Islands, as a decrease in foreign asset holdings. However, economically, such a decrease is not that meaningful, because it may not reflect a foreign portfolio investor selling asset backed securities. Beltran, Pounder, and Thomas (2008) provide a more thorough analysis of foreign banks' exposure to asset backed securities that account for these and other types of cross-holding issues. Their analysis suggests that in June 2007 the net foreign exposure to US ABS and MBS was $800bn. Our data indicates that holdings of Agency and non-Agency MBS and ABS total $1164bn in June 2007. This suggests that even our $204bn number is likely to be an overestimate.

5. Summary

Table 12 summarizes our results. The computations we have described so far are in the 7% column. The sum across the four sectors we have described is a net sale of $305bn. This is the "hole" in our computations. On the other hand, we have thus far neglected the government. In fact, as we will show in Section 5, the Federal Reserve and GSEs have played an important role in absorbing some asset sales in the current crisis.

We also present a 12% case to show the sensitivity of the computations to the assumed rate of repayment. The various sensitivity analyses suggest that we can be confident in asserting that the hedge fund and broker/dealer sector were net sellers, while the banking sector was a net buyer. The insurance sector may well have been neither net buyer nor seller. Since any errors compound when computing the total, the precision of the total estimate of $303bn is likely to be wide.

The central pattern that emerges from the data is the differential behavior of the hedge fund and broker/dealer sector versus the banking sector. In the next sections we will attempt to analyze why the banking sector may have behaved differently than the other parts of the financial system.

6. Government

a. Federal Reserve/Treasury

Table 13 provides data on an important intervention of the government in the banking system. The table is reproduced from Caballero and Kurlat (2009). The three Maiden Lane facilities work as follows. A collection of "toxic" assets has been removed from a financial institution (AIG or Bear Stearns) and placed in an entity where the government has an equity interest. As a result, JP Morgan (in the case of Bear Stearns) and AIG do not bear all of the risk associated with losses on the underlying assets. The Maiden Lane facilities essentially remove the economic risks associated with some assets from financial institutions' balance sheets.

The Citigroup and Bank of America facilities are much larger in size and arose as an attempt to stabilize these institutions. A large collection of toxic assets has been "ring-fenced" but remains on the banks' balance sheets. The government shares any gains/losses in the ring-fenced assets. Again, the economic risks of these assets have been partly transferred to the government. However, for accounting purposes, these assets remain on the banks' balance sheets.

The interventions as reflected in Table 13 do not directly identify the government as an asset purchaser. In the biggest cases, the assets remain on banks' balance sheets and are therefore reflected in previous computations. However, the fact that the government has accepted some of the risk and losses associated with bank assets is important in diagnosing why banks have behaved differently than other financial sectors. The banks have not been forced to sell these assets as a result. Moreover, if banks have been averse to risk taking, say due to a lack of equity capital as modeled in He and Krishnamurthy (2008, 2009), then one can argue that the banks' capacity to carry risky assets on balance sheet has expanded as a result of these government interventions. This intervention underscores that the banking sector is different from other sectors and helps understand the differential behavior as documented in Table 12.

b. Federal Reserve and GSE Purchase of MBS

The Federal Reserve has purchased Agency mortgage-backed securities directly in the secondary market. This program was initiated in the fall of 2008 and as of March 25, 2009, the Federal Reserve had purchased $246bn of MBS debt (Source: Federal Reserve H4). This purchase can explain part of the $303bn hole found in Table 12. However, note that the

government has only been active in the Agency MBS market – which is the low risk segment of the MBS market – and it has not purchased any non-Agency debt.

Table 14 reports balance sheet data on the mortgage GSEs (Fannie Mae and Freddie Mac) from the monthly volume reports that they publish. The table reports the holdings of Agency and non-Agency MBS for each entity as well as the total holdings. We also report the total amount of MBS that the agencies have guaranteed at each date.

Ginnie Mae is another mortgage guarantor. Over this period, Ginnie Mae guarantees a total of $395bn of mortgages. Since Ginnie Mae does not have a portfolio of MBS, we do not include Ginnie Mae in Table 14. As real estate prices fall, it is likely that the agencies will suffer losses on the guarantees that they have written.

From Table 14, total holdings of Agency MBS rise by $168 bn. Holdings of non-Agency MBS falls by $56bn, for a total change of $112bn. These figures can also help to fill the hole in Table 12. However, since it is well known that the GSEs have been purchasing securities in the primary market thereby supporting residential loans, much of this increase might just reflect their actions in the primary market rather than the absorption of asset sales by hedge funds or broker/dealers. Because the primary market issuance activity has been accounted for in the 7% repayment rate assumed in our earlier computations, $112bn is an upper bound estimate of the true asset purchases that GSEs performed in the current crisis.

7. Liabilities

We next examine the liability side to investigate how banks financed the asset acquisitions in the crisis.

a. Repo and Deposits

Table 15 presents data on adjustments on some key liability side variables. The top panel provides a picture of changes in the repo market. The total value of repo financing to commercial banks and broker/dealers has fallen by close to $1.5tn. However, keep in mind that measured changes in repo volume is most subject to the double counting problems that we have discussed earlier in Section 2.

The contraction in repo financing shown in Table 15 is consistent with the rise in repo haircuts in Table 5. It is also consistent with the deleveraging of the broker/dealer and hedge fund sector. These sectors are heavily dependent on repo financing for carrying out their trading operations. Thus the contraction in repo should be expected to affect these sectors strongly.

Note that almost any buyer who depends on repo financing is likely to have suffered during the crisis. For example, while we have not included private equity funds in our computations, it is likely that any such investors wishing to purchase ABS will also be limited by the lack of repo financing (see related discussion in footnote 14).

The bottom panel of Table 15 presents data on the banking sector and provides another data point explaining why the banking sector is different. Note that checkable deposits and small time and savings deposits rise by nearly $800bn. On the other hand, large time deposits fall by $200bn. It is likely that the bulk of the former category consists of FDIC insured deposits. Thus, the access to a deposit base and the insurance provided by the government through the FDIC serve as a source of debt financing to the banking sector. Apparently, this financing source is unique to commercial banks and cannot be enjoyed by any other parts of the financial system.

The last line in Table 15 shows that corporate bonds outstanding rises by $528bn. Much of this rise is due to the FDIC's Temporary Liquidity Guarantee Program (TLGP). The TLGP allows banks to issue senior unsecured debt with a maximum three year term. The FDIC insures default on these bonds for a fee of 25 to 50 basis points. These bonds are also a source of debt financing that is unique to the banking sector. The bulk of bond issues tied to TLGP occur in the Q4 2008 and Q1 2009. As of March 31, 2009 banks had issued $336bn of bonds under this program.[12]

There is another form of government-backed financing that banks have used over this crisis. The Federal Home Loan Banks make loans, called "advances", available to banks to provide liquidity against mortgages held by these banks. During normal periods, these advances help provide liquidity to banks in bridging the period between when a mortgage loan is originated and when it is securitized. The Federal Home Loan Banks are a GSE and fund themselves by issuing debt which carries the implicit guarantee of the US government. Thus, banks have access to a financing source that is, indirectly, backed by the government. The interest rates on the advances have been below LIBOR during much of this crisis. Ashcraft, Bech, and Frame (2008) describe the Federal Home Loan Bank system in greater detail, and document how it has been a significant source of liquidity to banks during the current crisis.

Advances in 2006 averaged $640bn. In 2007 and 2008, they averaged $900bn.[13] Both the size and the increase in advances underscore the existence and use of a significant funding source that has been available to banks but not other parts of the financial system.

[12] Data source: http://www.fdic.gov/regulations/resources/tlgp/reports.html.

[13] There are finer patterns that match the dynamics of the crisis. As of December 31, 2007 the total outstanding advances rose to $875bn. As of September 30, 2008, advances were at a peak of $1,011bn, before falling to $928bn on December 31, 2008. The outstanding advance further falls to $817bn on March 31, 2009.

b. Leverage and Capital

Table 16 provides data from the FDIC on the top 19 commercial banks in the US as of Q1 2009 (as listed by Bloomberg WDCI). From the FDIC data, measured book leverage in Q4 2007 is 10.4, and declines to 10.0 in Q1 2009.

There are important reasons to question the accuracy of this measure of leverage. First, the equity capital from FDIC data in Q1 2009 is measured as $763bn. However, as Acharya, Gujral, and Shin (2009) have stressed, much of the equity capital raised in 2008 from the U.S. Treasury was in the form of hybrid debt (preferred stock) rather than common equity, which implies that it would be inappropriate to call this amount "true equity capital." If we adjust the equity capital down for such preferred stock, we find that the true capital of the banking sector is $530bn. At this adjusted measure of capital, leverage in Q1 2009 is 14.4.[14]

In fact, there are further reasons to believe that the true leverage is even higher. As we have noted earlier, it is likely that banks have overestimated the value of their assets and have not taken write downs in a timely fashion (see Laux and Leuz, 2010, or Vyas, 2010). Much of the assets on bank balance sheets are not subject to fair value accounting, giving banks considerable discretion in accounting for any losses. Moreover, even for the assets that are subject to fair value accounting, a considerable amount is level 3 assets which are marked-to-model. For the banks in Table 16, the total level 3 assets on these 19 banks' balance sheets are $225bn.

The Bloomberg WDCI data we reference in Table 3 indicates that banking sector has taken write downs and losses of $500bn in the crisis up to Q1 2009. Yet most estimates of the losses that the banking sector will eventually suffer are a multiple of this number. For example, the IMF Global Financial Report of April 2009 estimates that total losses of the banking sector will exceed $1.6tn.

Suppose we lower the value of assets by $150bn to be more reflective of the true value of assets. Note that this $150bn mark-down represents an extremely modest estimation of the true extent of asset overvaluation. Then, the measured leverage rises to 19.6. If we lower the value of assets by a modest $300bn, then measured leverage rises to 31.8.

The above computations are based on book leverage. The market value of equity of the 19 commercial banks in Table 16 in Q4 2007 was $827bn. In Q1 2009, their market value of equity was $285bn. Based on this data one can further conclude that market leverage increased dramatically over this period.

[14] Throughout the latter part of 2009 as financial conditions improved, banks have raised common equity from private sources, paying back the TARP money. It seems likely that leverage fell through this period.

These computations suggest that the commercial banking sector has increased its leverage dramatically in this crisis, contrary to simple leverage computations based on FDIC data. Our computations also suggest the sources of the increase in leverage. First, fixing bank liabilities, if the value of assets on bank balance sheets falls, then leverage will rise. Asset prices clearly fell over the Q4 2007 to Q1 2009 period, and as our computations based on losses of $150bn and $300bn suggest, the fall in prices can have a dramatic effect on leverage. Second, if the banking sector acquires more assets and this purchase is financed predominantly by debt, then again leverage must rise. Our computations suggest that the banking sector did acquire assets. Moreover, the funds for this asset purchase came largely from government-backed debt financing as well as Treasury purchases of preferred shares/hybrid debt. Our computations suggest that this factor can also have a significant impact in increasing leverage.

8. Discussion

a. Summary

The conclusions we draw from the data is that the contraction in repo market financing hit the non-bank financial sector and caused deleveraging. The government has purchased some of these assets, particularly in the agency-backed MBS market. The government has also indirectly helped the banking sector absorb troubled assets. It has done this through one-off structures where risk is removed from bank balance sheets. It has also done this through offering debt guarantees which allow the banking sector to raise cheaper financing.

How accurate is our analysis and what have we missed out? As we have emphasized, our estimates are subject to considerable uncertainty. However, our sensitivity analysis suggests that our main *qualitative* conclusions are likely valid. The shocks that have affected the financial sector are so severe that one does not need fine-tuned computations to get a sense of the scale of adjustment. Moreover, while we have not considered all potential buyers, it is still likely that the commercial banking sector and the government are the only meaningful buyers in the troubled asset markets during this recent crisis. The reason is simple: Only the commercial banking sector has had access to stable funding through the crisis. Almost any other sector – e.g., private equity funds, Warren Buffet, etc. – will have to rely on repo financing to buy

securities, and the contraction in repo will hinder such buying activity.[15] Thus, while such activity has been present, it is likely to be quantitatively small.[16]

b. Theory: Leverage and Equity Risk-Capital Constraints

It is widely accepted that asset prices on many securities including asset-backed securities were low in the crisis period of 2008, reflecting not only impairment of the cash-flows due from these securities, but also unusually high risk and liquidity premiums (see, for example, Krishnamurthy, 2010, for evidence on high premiums). The most common explanations of the high risk and liquidity premiums are theories in which there are frictions to the financing extended to intermediaries, and a worsening of these frictions causes intermediaries to sell assets at fire-sale prices, become more risk-averse, and/or reduce liquidity provision to security markets. We ask, how does the data on asset trades and financing inform us about the relevance of these different friction-based mechanisms?

We focus on two broad classes of theories: leverage-constraints theories and equity risk-capital constraints theories. Both theories start with the assumption that intermediaries are constrained in raising more equity. The leverage-constraints theories emphasize that the amount of debt financing available to an intermediary is subject to a leverage constraint, i.e., lenders will set a maximum leverage ratio (for example, the inverse of haircut). Therefore the maximum funding that an intermediary can ever obtain is capped, which in turn affects the intermediary's asset demand. In contrast, the equity risk-capital constraints theories impose no limit on the amount of debt financing available to the intermediary. However, the theory links the amount of equity capital to the effective risk-aversion of the intermediary, which in turn determines the intermediary's demand for risky assets.

Clearly, these theoretical mechanisms can apply to either sellers or buyers in the intermediary sector. In our data, broker/dealers and hedge funds appear to be sellers, while banks appear to

[15] As an example, news reports suggest that BlackRock Asset Management purchased asset-backed securities during the crisis. From their SEC filings, BlackRock's assets under management in Fixed Income funds decrease from $513 billion to $474 billion from Q4 2007 to Q1 2009. Similarly there are news accounts of private equity funds pursuing purchases of commercial banks (http://www.nytimes.com/2009/08/27/business/27bank.html). Note that this is not purchases of asset-backed securities, but purchases of banks. Moreover, it seems possible that the interest driving these purchases is the access to stable funding enjoyed by the banking sector.

[16] Another possible sector we have left out of the analysis is long-only investors, such as private pension funds. The flow of funds reports total assets of pension funds of around $5tn. However the bulk of these assets are in corporate equities or mutual funds. The increase in holdings of GSE securities (which includes both MBS and straight Agency debt) plus all corporate and foreign bonds over the relevant period is about $70bn. Note that this figure likely includes a majority of debt securities which are not of interest for our analysis.

be buyers. We will thus be interested in understanding how these theories can be applied to both buyers and sellers.

b.1 Leverage Constraints

Geanokoplos and Fostel (2008), Adrian and Shin (2009) and Brunnermeier and Pedersen (2009) are notable examples of leverage-constraints theories. The theories have two components. First, the amount of debt financing available to an intermediary, or its debt capacity, is proportional to the equity capital of the intermediary times a leverage multiple, where the multiple is set by lenders. Second, the demand for assets by the intermediary is a function of the total funds (equity plus debt) available to the intermediary.

Denote by E the equity capital of the intermediary, and denote by $l^{\max}$ the maximum leverage that lenders will allow the intermediary to carry. That is to say, the maximum debt financing available to the intermediary is $\left(l^{\max}-1\right)E$. For example, in the case of repo, $l^{\max}=\frac{1}{haircut}$. Then, the total funding available to an intermediary, equity plus debt, is $E\times l^{\max}$. In the leverage-constraints models, we have

$$\text{Demand for Securitized Assets by Intermediaries} = Demand^{+}\left(E\times l^{\max}\right),$$

where the "+" sign indicates that demand is increasing with the total funding capacity. In studying crises, many leverage-constraints models (e.g., Brunnermeier and Pedersen (2009)) focus on the case where the intermediaries saturate their funding capacity so that the demand is equal to the available funding, $Demand\left(E\times l^{\max}\right)=E\times l^{\max}$. Therefore, higher haircuts cause $l^{\max}=\frac{1}{haircut}$ to fall in the crisis, and in turn reduce intermediaries' demand. These theories also suggest that the intermediaries' losses cause E to fall, leading to a reduced demand, as modeled in Gromb and Vayanos (2002).

Geanokoplos and Fostel (2008), Adrian and Shin (2009) and Brunnermeier and Pedersen (2009) describe the leverage-constraints as applying to sellers during a crisis. Tighter leverage constraints lead to deleveraging and asset sales. In the models, the sales are absorbed by agents who assign lower valuations to the asset and are typically unmodeled. This is a weakness of the models, because it seems apparent from our data that important buyers, i.e. commercial banks, are also likely subject to financing frictions.

There are models of borrowing constraints which are explicit in modeling buyers, where the buyers are leverage-constrained themselves during a fire sale. Allen and Gale (2005)'s "cash-in-the-market" model is a leading example for this class of models (see also Shleifer and Vishny's

(1992) analysis of fire sales and debt capacity). This theory pins down the asset price by the limited amount of cash/liquidity, $E \times l^{\max}$, held by surviving financial intermediaries, as these surviving financial intermediaries are the marginal buyers of the asset.[17]

b.2 Equity Risk-Capital Constraints

Xiong (2001), He and Krishnamurthy (2008, 2009), and Brunnemeier and Sannikov (2010) are examples of equity risk-capital models. In these models, the intermediary sector, which is constrained in raising equity financing, faces no constraint in raising debt financing (i.e., $l^{\max} = \infty$). Relative to the leverage constraints models, this theory works through the effect of limited equity capital on the effective risk aversion of the intermediary, rather than through the debt capacity of intermediaries as in the leverage constraints models. Intermediaries are risk-averse in the sense that they make decisions to reduce the likelihood of bankruptcy, trying to avoid either the costs of financial distress (from the institution's view) or the personal costs in the case of job loss (from the manager's view).[18] Also, note that without constraints on raising debt, this theory generally implies that the intermediary's asset demand is an interior solution of its portfolio choice problem. This is unlike the leverage-constraint theories in which the demand for assets is equal to the total financing available to the intermediary.

In the He and Krishnamurthy model, losses suffered by the intermediary directly reduce the wealth and consumption of the manager who runs the intermediary. Therefore, because purchasing a risky asset rather than a low risk asset may lead to distress, demand for risky assets is low in states of the world where distress probabilities are already high. When many intermediaries are close to distress, the demand across all intermediaries is low. Therefore, we have:

$$\text{Demand for Risky Securitized Assets by Intermediaries} = Demand\ (\text{Likelihood of Distress}).$$

And, because having more equity capital implies a lower risk of distress, we have:

[17] Bank-run explanations (Diamond and Dybvig, 1983, Allen and Gale, 2005, Gorton and Metrick, 2009, and He and Xiong, 2010) have similar predictions, although not stated explicitly in terms of debt constraints and haircuts. In these models, either the realization of a liquidity shock or deteriorating fundamentals trigger a bad equilibrium in which there is a disintermediation and asset sale.

[18] Another exposition of the equity risk-capital theory focuses on risk-based regulatory capital considerations for commercial banks. Regulatory capital requirements penalize holdings of risky assets in favor riskless assets (e.g. Kashyap and Stein, 2004). Thus, when losses erode capital levels, banks respond by shifting their portfolios to favor riskless assets. This in turn implies that banks require a higher risk premium to purchase risky assets, causing asset prices to fall. This theory shares the predictions of the equity-capital/risk-aversion theory, as the reasoning relies on the relation between asset demand, equity capital and asset riskiness.

$$\text{Demand for Risky Securitized Assets by Intermediaries} = Demand\left(\overset{+}{E}\right).$$

Losses suffered by the intermediary sector in the crisis reduce equity capital levels, which cause the effective risk aversion of the intermediary sector to rise. This in turn translates to a lower demand for risky assets, and a lower equilibrium asset price.

Xiong (2001) and Brunnemeier and Sannikov (2010) model the intermediary sellers of risky assets. In their models, reductions in E cause intermediaries to become more risk averse[19] and sell assets to an unconstrained sector. These buyers have a lower valuation for assets, but are otherwise unmodeled. In Xiong (2001), the buyers are interpreted as long-run investors, and in Brunnemeier and Sannikov (2010) they are interpreted as households. Neither of these models is applicable in thinking about the banking sector's asset growth because these models predict that reductions in E will cause asset prices and holdings to fall. Xiong (2001) predicts a rising intermediary leverage in the crisis, while the intermediary sector deleverages in the crisis in Brunnemeier and Sannikov (2010).

In the He and Krishnamurthy (2008, 2009) model, the buyers are also equity-constrained. In their model, in equilibrium, these equity-constrained intermediaries have to absorb all asset sales. As a result, when equity capital falls and given no leverage constraints, the intermediary sector substitutes by raising some debt, causing leverage to rise. The rise in leverage of the intermediary sector during crises is a distinguishing prediction of the He and Krishnamurthy model.

c. Facts and Theories

We now revisit the facts and consider how to fit these theories together to understand what transpired in 2008.

1. The leverage-constraint theories fit the facts surrounding the hedge fund and broker/dealer sector. Repo haircuts rise in the crisis and the quantity of repo funding contracts. It is commonly understood that the hedge fund and broker/dealer sectors rely primarily on repo financing for their borrowing needs. The hedge fund and broker/dealer sector are also significant sellers of securitized assets. Each of these facts is consistent with the leverage-

[19] In Brunnemeier and Sannikov (2010), intermediaries have linear preferences but are restricted to only have positive consumption. As a negative consumption implies a utility of minus infinity, this is isomorphic to assuming that intermediaries are risk averse.

constraints explanations of Gromb and Vayanos (2002), Geanokoplos and Fostel (2008), Adrian and Shin (2009), and Brunnermeier and Pedersen (2009).

2. While we have not provided data on leverage of the broker/dealer and hedge fund sector, it is likely that leverage of these sectors falls, consistent with the empirical analysis in Adrian and Shin (2009). If we take the fall in leverage of these sectors as factual, then it can be rationalized by the higher-haircut models of Geanokoplos and Fostel (2008), Adrian and Shin (2009), and Brunnermeier and Pedersen (2009), where intermediaries choose the maximum leverage given a haircut.

3. The equity risk-capital constraint model of He and Krishnamurthy (2008, 2009) is not consistent with the fall in leverage of the broker/dealer and hedge fund sectors. The model of Brunnermeier and Sannikov (2010) is consistent with the fall in leverage.

4. The leverage-constraints models do not fit the facts surrounding the banking sector. First, leverage of the banking sector rises. Second, banks have had access to ample liquidity throughout the crisis and have as a choice not saturated their government financing. If banks were constrained in raising debt at the margin, we should observe them saturating all forms of debt financing. This has not happened. For example, the total limit of the FDIC debt guarantee program (the TLGP program discussed in Section 6.a) is $769bn, but banks have never reached more than 50% of that cap.[20] In addition, banks have had access to Federal Reserve discount window loans throughout the crisis and have used such access in moderation. From a pure liquidity standpoint, the commercial banking sector in particular has had access to liquidity. Thus, to the extent that asset values have been low, such a situation is inconsistent with models of leverage-constrained buyers.[21] The models of Gromb and Vayanos (2002), Allen and Gale (2005), Geanokoplos and Fostel (2008), Adrian

[20] According to TLGP, the maximum debt that can be issued by a bank is limited to 125% of the par value of the bank's senior unsecured debt that was outstanding as of the close of business September 30, 2008 and that was scheduled to mature on or before June 30, 2009. Banks only have used 43.7% of cap on March 31, 2009, and 43.7% on June 30, 2009 (source: http://www.fdic.gov/regulations/resources/tlgp/reports.html).

[21] Allen and Gale (1994), Diamond and Rajan (2009), and Holmstrom and Tirole (1998) study a dynamic version of the leverage-constraints model. In their models, dynamic considerations lead agents to hold a buffer of liquidity at time 0, rather than saturating the maximum borrowing capacity immediately. In Allen and Gale and Diamond and Rajan, the behavior is due to the anticipation of future fire sales. In Holmstrom and Tirole, the behavior arises because the possibility of a binding constraint makes agents' current value function concave. These models can rationalize low asset prices as well as banks' ex-ante decision not to saturate debt capacity. However, they require that banks expect that the Fed's lending and liquidity facilities will be insufficient to meet anticipated borrowing needs, which seems at odds with the unprecedented level of lending by the Fed. Also, this theory does not speak to high leverage directly.

and Shin (2009) and Brunnermeier and Pedersen (2009) do not fit the facts regarding the commercial banking sector.

5. The equity risk-capital constraints model of He and Krishnamurthy (2008, 2009) fits the facts on the banking sector. Capital levels have fallen in the banking sector. Banking leverage has risen in the crisis. Moreover, the equity capital constraint model can rationalize why banks have not saturated their government backed financing. While borrowing using government-backed debt does give a bank more resources to invest, such actions also increase leverage and in turn the probability of financial distress. The implied cost of leverage can help rationalize why banks have not saturated their government financing.

6. Prices of securitized assets are best understood by focusing on the asset trading decisions of the commercial banking sector. We say this because the banking sector is the only significant private sector acquirer of securitized assets. Moreover, the banking sector has had access to the cash required to buy assets. The broker/dealer and hedge fund sectors are essentially forced sellers, and the government sector has essentially executed "market orders." Since the banking sector has been free to choose its holdings of securitized assets, it is the "marginal investor" who determines the price in securitized assets during the crisis.

Putting these points together, we think that the right model to understand the adjustments in 2008 is the one that emphasizes leverage constraints on the shadow banking sector (hedge funds, broker/dealers, etc.) and at the same time emphasizes equity risk-capital constraints on the traditional commercial banking sector. To some extent, the recent crisis reflects a reintermediation of flows into the traditional banking sector, since the commercial banking sector has had access to stable government-backed debt financing.[22] However, equity risk-capital constraints of the banking sector affect the quantity and pricing in this transfer, as in He and Krishnamurthy (2008, 2009).[23] As noted in point 6 above, to understand the behavior of

[22] Gatev and Strahan (2005) document "reintermediation" during disruptions in the commercial paper market, and attribute the FDIC deposit insurance (which is only enjoyed by commercial banking sector) to this phenomenon.

[23] There is another important theory linking government-backed financing and bank decisions that requires discussion. The classic risk-shifting theory (Jensen and Meckling, 1976) as applied to the banking sector is that banks exploit the government guarantee, turning risk-loving, and purchase the riskiest assets. On one hand, this theory is consistent with the fact the banks have increased asset holdings and have raised leverage. On the other hand, this theory seems at odds with a number of other stylized facts. First, even in their security purchases, banks have concentrated on buying the lower risk Agency-backed MBS, rather than on seeking out the riskiest ABS to purchase. Second, the liquidity problems and apparent high market prices of risk seem most pronounced on the riskiest assets. Yet, if banks had strong reasons for buying the riskiest assets, these assets would have the lowest risk premia and the least liquidity problems. Finally, risk-shifting incentives would lead banks to saturate the debt guarantees, but the data suggest otherwise.

asset prices it is sufficient to examine the pricing of buyers, and this pricing condition is best described by the He and Krishnamurthy model.

To provide some sense of the capital and pricing effects in the reintermediation back into the banking sector, consider the following thought experiment. Our computations suggest that banks increase their holdings of securitized assets by $550bn. Assuming mortgage returns are distributed normally with annual standard deviation of 15%, then the 1% value-at-risk on this position is $190bn. The equity capitalization of the banking sector is around $763bn, so this calculation suggests that fully one quarter of the capital must be devoted to the risk in these positions. One can expect that the banks must be offered a high return to compensate them for the capital used in acquiring these positions.

This viewpoint is also consistent with evidence of a bank credit crunch. As Ivashina and Scharfstein (2009) document, new bank lending to firms has fallen sharply in the crisis. A bank with limited capital can either make a new loan or absorb the assets being sold by the shadow-banking sector. Because the bank demands a high return for tying up its capital in purchasing securitized assets, it will also require a high return in making new loans. Thus, we can expect that banks will restrict the supply of new loans, as well as raise lending standards and loan interest rates.

Independent of our specific findings, we hope that our paper demonstrates the value of this exercise, and points toward the type of data that is needed in order to understand the current and future financial crises. In real time, it would be useful to policymakers to understand the nature of the varying constraints affecting the financial sector during a crisis. With the benefit of hindsight, we have made some progress in this dimension. However, it is also clear that in many places sharper data would have been helpful. We think that debates about the future regulatory environment should take account of these data considerations.

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Mortgage and Credit Related Securities	Outstanding
Total ABS (including auto, credit card, home equity, manufacturing, student loans, CDOs of ABS)	2480
ABS CDOs	400
Mortgage Related	8990
Agency GSE MBS	6094
Non-Agency MBS	2897
Corporate Bonds	6043
Asset-Backed Commercial Paper	1250
Total for Securities	17513

Table 1: Mortgage and Credit Securities ($ billions)

Data source: Securities Industry and Financial Markets Association (SIFMA) and Acharya, Schnabl, and Suarez (2009). This table lists the type of assets and their outstanding volumes we focus on in this study. ABS, CDO, GSE, and MBS stand for asset-backed securities, collateralized debt obligations, government-sponsored enterprises, and mortgage-backed securities, respectively. Outstanding volume of asset-backed commercial papers is from Acharya, Schnabl, and Suarez (2009). All other figures are from SIFMA. All figures represent the outstanding amounts measured in 2007.

Financial Institution	Total Assets
Commercial Banks	11192
Insurance Companies	6308
GSEs	3174
Brokers and Dealers	2519
Hedge Funds	5530

Table 2: Financial Institution Assets in 2007($ billions)

Data source: Flow of funds, SEC filings, and Hedge Fund Flow Report by Barclay Hedge. This table provides a list of the total asset holdings by the five major categories of asset holders: commercial banks, insurance companies, GSEs (Fannie Mae and Freddie Mac), broker/dealers, and hedge funds. Data for commercial banks, insurance companies, and GSEs are from the Flow of Funds. Data for the Broker/Dealers sector are from their SEC filings. Hedge Funds sector's data are from the Hedge Fund Flow Report by Barclay Hedge. All figures correspond to the holdings at the end of December 2007.

Financial Institution	Total Losses
Commercial Banks	500
Insurance Companies	207
GSEs	153
Brokers and Dealers	100
Hedge Funds	170

Table 3: Financial Institution Losses up to March 2009 ($ billions)

Data source: Bloomberg WDCI and authors' computation. This table provides a breakdown of the write-downs and losses (collectively referred to as losses) suffered, by the major category of asset holders, from the start of the crisis in 2007 to March 2009. Hedge Funds sector's losses are from the authors' own estimation based on the Hedge Fund Flow Reports by Barclay Hedge (see Section 3.a Hedge Funds). All other losses are from Bloomberg WDCI.

Strategy	Q4 2007	Q1 2009	Redemptions and Trading Losses
Convertible Arbitrage	42	11	31
Distressed Securities	176	69	107
Emerging Markets	353	125	228
Equity Strategies	538	303	235
Event Driven	162	57	105
Fixed Income	160	69	91
Macro	91	61	30
Merger Arbitrage	39	5	34
Multi-Strategy	224	122	102
Other	61	20	41
Sector-Specific	130	58	72
Hedge Fund Industry	**1975**	**973**	**1002**

Table 4: Equity Capital of Hedge Fund Industry ($ billions)

Data source: Hedge Fund Flow Reports by Barclay Hedge (2008, 2009). The table lists the equity capital of the hedge fund sector by various investment strategies from December 2007 to March 2009.

Security	Spring 2007	Spring 2008	Fall 2008	Spring 2009
US Treasuries (short-term)	2%	2%	2%	2%
US Treasuries (long-term)	5	5	6	6
Agency Mortgage-Backed Securities	2.5	6	8.5	6.5
Corporate Bonds, A-/A3 or above	5	10	20	20
Collateralized Mortgage Obligations (CMOs), AAA	10	30	40	40
Asset Backed Securities (ABS), AA/Aa2 and above	10	25	30	35

Table 5: Evolution of Repo Haircuts in the Crisis

Data source: Krishnamurthy (2009), who draws the data from the DTCC and investment bank reports. This table provides the evolution of repo haircuts from Spring 2007 to Spring 2009 across different types of debt securities with varying degrees of liquidity and credit risks.

Year End 2007	Total Assets	Trading Assets
Goldman Sachs	1120	453
Merrill Lynch	1045	375
Morgan Stanley	1020	317
Citigroup Global Markets	664	274
Bank of America Securities	922	308
JP Morgan Investment Bank	612	423
Lehman Brothers	691	313
Bear Stearns	395	138
Total	**6469**	**2601**

Table 6: Trading Assets of Broker/Dealers ($ billions)

Data source: SEC filings. This table provides total assets and trading assets of the main broker/dealers in the US as of December 2007. Goldman Sachs, Merrill Lynch, Morgan Stanley, Lehman Brothers and Bear Stearns are "pure" broker/dealers whose main business is in the broker/dealer industry. However, we do not have Q1 2009 data for Lehman Brothers and Bear Stearns. Bank of America Securities, Citigroup Global Markets, and JP Morgan Investment Bank are broker/dealer subsidiaries of larger bank holding companies that also own the top three (by any sensible measure) commercial banks in US.

Assets		Nov 2007	Feb 2008	March 2009
Goldman Sachs	Trading Assets	453	499	350
	Credit and Mortgage Related	93	89	40
Morgan Stanley	Trading Assets	375	446	259
	Credit and Mortgage Related	148	161	83
Merrill Lynch	Trading Assets	317	312	188
	Credit and Mortgage Related	122	124	59
Total Credit and Mortgage Related Assets		**363**	**374**	**182**

Table 7: Trading Assets of Investment Banks[24] ($ billions)

Data source: SEC filings. The table lists the trading assets and credit/mortgage related assets for the three "pure" broker/dealers in November 2007, February 2008 and March 2009. Trading assets include both the securities the firms hold for investment purposes and the securities that are reported under the heading *trading securities* in the SEC filings. Credit and mortgage related assets are a subset of the trading assets; we compute these assets by summing up the reported holdings of Agency and non-Agency mortgage-backed securities, asset-backed securities, and credit market securities. See Appendix for more detailed data construction.

Insurance Companies	Q4 2007	Q1 2009
AIG	184	45
Hartford Financial Services	30	17
Berkshire Hathaway	4	3
Allstate	23	12
Travelers	6	6
Liberty Mutual	17	15
CNA Insurance	11	7
Progressive	3	2
Total	**279**	**107**

Table 8: Mortgage and ABS Holdings of Top 8 Insurance Companies ($ billions)

Data source: SEC filings. This table lists the ABS and MBS holdings of the top 8 insurance companies in US.

[24] Goldman Sachs and Morgan Stanley, being non-bank-holding companies until late 2008 and not bound by the regulations for the bank-holding companies, used to file with the SEC according to a fiscal year that ends in November in every calendar year. On the other hand, Merrill Lynch, irrespective of its status as a non-bank-holding company, has been filing with the SEC following the same fiscal year schedule as any other bank-holding companies. So, the figures for Merrill Lynch in Table 7 correspond to December 2007, March 2008 and March 2009.

	Q4 2007	Q1 2009
Cash and Reserves	76	813
Securities	2253	2419
Loans and Leases	6807	7031
All Other assets	243	800
Total Financial Assets	**9379**	**11063**

Table 9: Assets of Commercial Banks ($ billions)

Data Source: Flow of Funds. This table provides data on the changes in the total financial assets of US commercial banks' balance sheet from December 2007 to March 2009. *Cash and reserves* refers to vault cash and reserves at the Federal Reserve. *Securities* includes all types of securities from Treasury securities to private CMO and non-agency MBS. *Loans and leases* represents a wide range of bank loans (including mortgage loans) and consumer/commercial lines of credit extended. *All other assets* are assets that do not fall under the first three categories. In calculating the above table, we exclude the data for bank holding companies, i.e. the data is L109 minus L112, to avoid double counting issues.

	Q4 2007	Q1 2009
US Chartered Commercial Banks		
ABS	84	140
MBS		
Agency and GSE-backed	929	1085
Privately Issued	272	237
Savings Institutions		
MBS		
Agency and GSE-backed	169	175
Privately Issued	111	47
Foreign Banking Offices		
Agency and GSE-backed Securities	57	45
Bank Holding Companies		
Agency and GSE-backed Securities	10	22
Banks in US Affiliated Areas		
Agency and GSE-backed Securities	27	23
Total Securities	**1659**	**1774**

Table 10: Holdings of Securities by Commercial Banks ($ billions)

Data sources: Flow of Funds of Federal Reserve, FDIC Statistics on Depository Institutions Report. This table presents the changes in holdings of MBS and ABS from December 2007 to March 2009 across different types of banking institutions. The ABS holdings are from the FDIC data based on Call Reports. The rest of the figures are from the Flow of Funds by the Federal Reserve Board.

	6/30/2007	6/30/2008	6/30/2009
Total:			
Agency MBS	570	773	752
Non-Agency MBS and ABS	594	458	498
Of Which, Foreign Official Holdings:			
Agency MBS	236	435	475
Non-Agency MBS and ABS	26	18	32

Table 11: Foreign Holdings of Asset Backed Securities ($ billions)

Source: U.S. Treasury Report on Foreign Portfolio Holdings of U.S. Securities. This table provides data on foreign holdings of agency MBS and non-agency MBS and ABS. The Treasury Report is annual and the quarterly data is not available.

	Securities	7%	12%
Hedge Funds	Agency, non-Agency, Other	**-492 to -754**	-456 to -682
Broker/Dealers	Only Non-Agency	**-205 to -472**	-172 to -261
Insurance Companies	Agency and non-Agency	**36 to -247**	62 to -206
Commercial Banks	Agency and non-Agency	**407 to 731**	490 to 814
Total (medium scenario)		**-305**	**-105**

Table 12: Summary of Private Sector Flows ($ billions)

This table summarizes the results of our analysis from Table 1 through Table 11. We list the types of securities included in our sale/purchase estimation and the lower and upper bounds on net purchases (sales if negative), assuming two scenarios on the repayment of existing assets (7% and 12%). The total net sales reported in the last row assume the medium scenario for all sectors' purchases/sales.

Facilities	Maximum Total Assets	First Loss Borne by Insured Party	% Exposure of Remainder	Net Maximum Exposure

Maiden Lane (Bear Stearns)	30	1	100%	29
Maiden Lane II (AIG)	20	0	100%	20
Maiden Lane III (AIG)	30	5	100%	25
Citigroup	306	29	90%	249
Bank of America[25]	118	10	90%	97
Total	**504**	**44**		**421**

Table 13: Federal Reserve/Treasury

Data source: Caballero and Kurlat (2009). This table provides data on various channels through which the Federal Reserve and the Treasury Department (collectively referred to as the US Government) directly intervened in the MBS and ABS markets. Maiden Lane facilities are legal entities that were set up by the Federal Reserve specifically to bear the losses arising from a collection of "toxic" assets previously held by Bear Stearns and AIG. Citigroup and Bank of America's assets totaling $424bn are "ring-fenced" by the Treasury department (see related discussion in footnote 12). Similar to the Maiden Lane facilities, all losses after the low-threshold first losses are borne by the Treasury Department.

	Q4 2007	Q1 2009
Fannie Mae		
Agency MBS	289	314
Non-Agency MBS	112	97
GSE Guaranteed Securities	2422	2640
Freddie Mac		
Agency MBS	405	548
Non-Agency MBS	234	192
GSE Guaranteed Securities	1382	1380
Total		
Agency MBS	694	862
Non-Agency MBS	346	290
GSE Guaranteed Securities	3804	4020

Table 14: Government-Sponsored Enterprises ($ billions)

Data Source: Monthly Volume Summaries from Fannie Mae, Freddie Mac (2007 and 2009). This table reports the holdings of Agency and non-Agency MBS by Fannie Mae and Freddie Mac. Also reported is the total amount of MBS that each agency has guaranteed at each date.

	Q4 2007	Q1 2009
Repo Agreements and Fed Funds		

[25] On January 16, 2009, Chief Executive Ken Lewis announced Bank of America has received the federal guarantee for $118 billion of toxic assets, most of which were accrued in its acquisition of Merrill Lynch. However, on May 7, 2009, after the "stress test" Bank of America tried to terminate this deal unilaterally, and in the end this facility failed. For the purpose of this paper, we include this facility because this facility exists during Q1 2009 (and all market players understand this fact).

Liabilities		
Commercial Banks	1327	463
Broker/Dealers	1223	419
Assets (main holders)		
Rest of the World	1100	583
Mutual Funds	713	603
Bank Financing		
Checkable Deposits	587	666
Small Time and Savings Deposits	4078	4755
Large Time Deposits	1927	1725
Corporate Bonds	688	1216

Table 15: Money Market ($ billions)

Data source: Flow of Funds. This table provides data on how financing environment has evolved for the broker/dealer sector and the commercial banking sector from December 2007 to March 2009. The top panel presents the changes in the repurchase agreement market as they affect these two sectors. The bottom panel shows the changes in other types of debt financing for the commercial banking sector.

	Q1 2009
Total Assets	7608
Total Liabilities	6845
Equity Capital	763
Preferred Stock (including TARP) raised in 2008	233
"True" Capital	530
Leverage at 763 of Equity Capital	10.0
Leverage in Q4 2007	10.4
Leverage at 530 of Equity Capital	14.4
Leverage if true Assets are lower by 150	19.6
Leverage if true Assets are lower by 300	31.8

Table 16: Top 19 Commercial Banking Leverage ($ billions)

Data source: FDIC. This table provides total assets, total liabilities, and various levels of equity capital for the collection of the top 19 commercial banks in US as of March 2009. These banks also correspond to the exhaustive list of US commercial banks that had major write-downs and losses due to the deterioration of the MBS, ABS, and other debt securities as listed on Bloomberg WDCI. Motivated by the fact that this group of banks held $225bn of level 3 assets as of March 2009, we carry out a mental experiment of what the leverage might be if the true assets were lower by $150bn and $300bn, respectively.

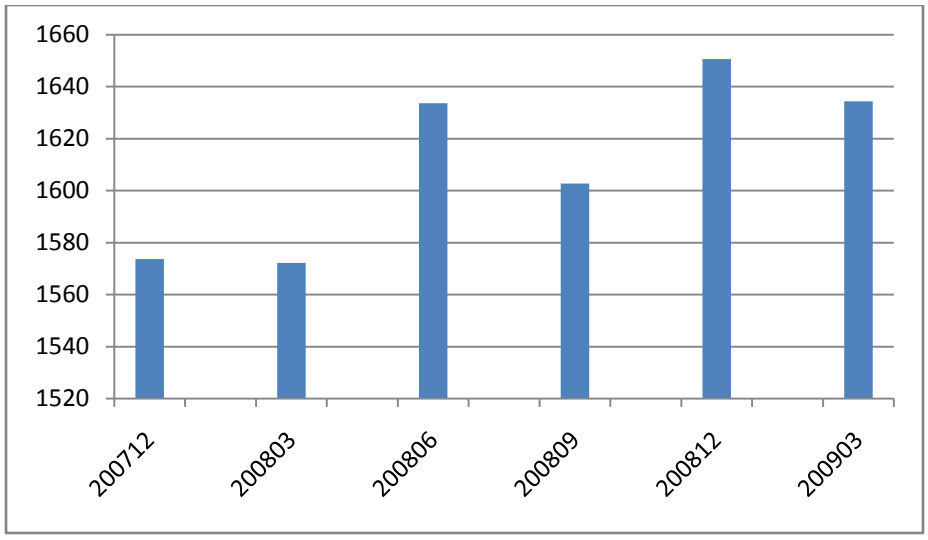

Figure 1: Total MBS Holdings of Banking Sector ($ Billions)

Data Source: Flow of Funds of Federal Reserve.

Appendix: Data Construction and Calculation

Hedge funds

Data Sources and Preliminaries

Asset Under Management (AUM) and loss estimates.

We obtain the asset under management (AUM) from Hedge Fund Flow Report by Barclay Hedge (2008, 2009). Both redemptions and trading losses contribute to the drop of AUM of the hedge fund industry. A significant fraction of these redemptions and trading losses are due to the hedge funds that liquidated all of their positions completely and went out of business. However, only surviving funds report the breakdown between redemption and trading losses, which is a decrease of $161bn from redemption and a loss of $317bn from asset trading. Based on this information, we assign 66.3% of the drop in AUM to trading losses in all of our computations.

Leverage information, both strategy-specific and overall average

For strategy-specific leverage information, we use the TASS hedge fund database which provides measures of leverage across different strategies as of 2006. We assume that this captures the leverage that hedge funds were using in Q4 2007, i.e. before the crisis affected the hedge fund industry.

We do not have strategy-specific leverage information for Q1 2009. Instead, we rely on Lo (2008) who provides the annual leverage information across the entire hedge fund industry during 2007 and 2008. Although useful, these annual leverages are of limited use to us since it is well known that the credit markets tightened considerably toward the end of 2008 (as reflected in the significant increase of the haircuts in Table 5); this suggests that the leverage of the hedge fund industry in January 2008 must be quite different from the leverage in December 2008. Since we are primarily interested in finding out the leverage ratio for Q1 2009, we ask if we can combine these two pieces of information (that average leverage ratio for 2008 is 2.3 and that hair-cuts on debt securities rose steadily throughout the year 2008) to arrive at a closer estimate of the leverage in Q1 2009. Specifically, we ask the following question. What does the final 2008 year-end leverage have to be in order to match two facts: (1) Haircuts double over the year 2008 (although we do not take a stand on what the level of the haircuts are); and (2) The average leverage ratio over the year 2008 is 2.3. The answer is a leverage ratio of 1.7 at the end of year 2008. We use 1.7 as the estimate of the leverage in Q1 2009 for all hedge funds regardless of their investment strategies in all of our later computations.

Main Calculations

As mentioned in the main text, we consider the following three scenarios to estimate the net sale (or purchase) of credit/mortgage related assets by the hedge fund industry.

Low Scenario: Only fixed income strategies hold credit/mortgage related assets. This strategy has an AUM drop of $91bn. Given the estimation that 66.3% of AUM drop is due to trading losses, the trading losses in credit/mortgage related assets are $60.3bn in this case.

Taking the AUM under fixed income strategies at Q4 2007 (which is $160bn) and the leverage ratio of the fixed income strategy (which is 4.5 according to TASS hedge fund database in 2006), we estimate the entire holdings of credit/mortgage related assets for the hedge fund industry to be about 720bn=$160bn x 4.5 in Q4 2007. We then calculate the asset holdings in Q1 2009 to be $117.3bn (we multiply the $69bn AUM in Q1 2009 by the leverage ratio 1.7). Taking into account the net repayment of 7% on existing assets, in (eq. 1), and applying the loss estimate of $60.3bn, we arrive at the estimate sale of $492bn = $720bn x (100%-7%)-$117.3bn-$60.3bn by the hedge fund industry in this scenario.

Medium Scenario: Only fixed income and macro strategies hold credit/mortgage related assets. The total drop of AUM is $121bn under this scenario and the trading loss estimate is $80.2bn. Our calculation is performed in the same way as above and is omitted here; the only difference is that we do the same exercise as above with macro strategy and combine the resulting net sale with the net sale of fixed income strategy. The estimate sale is $546bn in this case.

Upper Scenario: Credit/mortgage related assets are held by a broad class of hedge funds which includes the following strategies – distressed securities, fixed income, and macro as well as a fraction of the multi-strategy and sector specific strategy funds.

To determine the fraction of multi-strategy, we assume constant proportionality and assign the proportion of the combined capital of distressed securities, fixed-income, and macro in relation to the industry total capital excluding multi-strategy, other, and sector specific strategies for both times, Q4 2007 and Q1 2009. To determine the fraction of sector specific strategy, we assume that it is proportional to the share of two industries in GDP, real estate and finance. Since this broad class of funds is close to the entire hedge fund sector (by the size of AUM), we use the average leverage, instead of sector specific leverage, of the entire hedge fund sector for Q4 2007: this is 2.8 according to Figure 3 in Lo (2008).

Under this scenario, the total drop of AUM is $514bn and the trading loss estimate is $170bn. We then follow the same steps as in the Low/Medium Scenarios to reach the estimated sale of $754bn of credit/mortgage related assets by the hedge fund sector.

Brokers and Dealers

Data Sources and Preliminaries

The Flow of Funds Report by the Federal Reserve does not provide detailed enough information on the breakdown of assets so that we are not able construct an accurate measure of the credit/mortgage related assets by this sector. So, we rely on the individual SEC filings of major broker/dealers in US instead.

We take the top eight broker/dealers in Table 6 as the entire broker/dealers sector and compute their trading assets based on information from their individual SEC filings. Our goal is to estimate what fraction of the trading assets in the broker/dealer sector can be counted as credit/mortgage related assets. To this end, we first restrict our attention to the top three broker/dealers (Goldman Sachs, Morgan Stanley, and Merrill Lynch) and calculate the fraction of credit/mortgage related assets in their trading assets. Then we extrapolate this fraction to the other five firms in Table 6 based on the assumption that Goldman Sachs, Morgan Stanley, and Merrill Lynch are representative of the broker/dealer sector. We take this approach due to three reasons: 1) Goldman Sachs, Morgan Stanley, and Merrill Lynch are the only meaningful "pure" broker/dealers remaining in this sector since Lehman Brothers and Bear Stearns disappear out of the industry during 2008; 2) the other three broker/dealers in Table 6 are subsidiaries of the three largest bank holding companies in US, which also own the three largest commercial banks in US, and are likely to be under non-negligible influence by the considerations of the commercial banking operation. This behooves us to focus solely on Goldman Sachs, Morgan Stanley, and Merrill Lynch to obtain a relatively clean estimate for the holdings of credit/mortgage related assets; 3) the broker/dealer subsidiaries mentioned in 2) do not report detailed enough information on their holdings of credit/mortgage related assets because their holding companies report on a consolidated level, which does not provide sufficient information for analysis.

Most of the firms in Table 6 have an item called "Financial Instruments Owned" on their balance sheet, which includes derivative contracts, US government and agency securities, sovereign debt, corporate equity, MBS and ABS, etc.[26] We label this category as "Trading assets." For the top three firms (Goldman Sachs, Morgan Stanley, and Merrill Lynch), whose credit/mortgage related holdings are our focus, we try to exclude derivative contracts, sovereign debt, US government and agency securities,[27] and corporate equity to obtain an estimate of "credit/mortgage related assets." We include corporate debt because this category includes "other debt securities" such as private MBS, which we are mostly interested in.

Details on how we construct the measure of credit/mortgage related assets are provided below for each of the top three firms.

[26] Note, however, that all of them exclude repurchase agreement transaction volumes.

[27] It is possible that this treatment will exclude part of agency MBS holdings. However, by reading the notes of SEC filings, usually agency MBS are in the category of MBS, not in "US government and agency securities."

Goldman Sachs: Trading assets are "Total financial instruments owned, at fair value" in the balance sheet. Detailed break-down of these assets are in Note 3 in Goldman Sachs' 10-K filing. We compute the sum of "mortgage and other asset-backed loans and securities" and "corporate debt securities and other debt obligations" to be "credit/mortgage related assets."

Morgan Stanley: Trading assets are "Total financial instruments owned, at fair value" in the balance sheet with detailed decomposition. We take "corporate and other debt" to be "credit/mortgage related assets."

Merrill Lynch: Merrill Lynch has a slightly different reporting system than the first two. From the balance sheet, we sum up "Trading assets, at fair value" and "Investment securities" (with detailed decomposition in Note 5)[28] to reach the estimate of "trading assets." To calculate "credit/mortgage related assets," we take "Corporate debt and preferred stock" and "Mortgage, mortgage-backed, and asset backed securities" from the "Trading assets, at fair value" and add "Available-for-sale", "trading", and "held-to-maturity" securities from the "Investment securities" (with data in Note 5). Interestingly, Merrill Lynch reports that 93% of these securities are non-agency and agency MBS in the 10-Q filing of Q1 2009.

As reported in Table 7, these top three broker/dealers have a total sale of $156bn =$363bn x (100%-7%)-$182bn, before adjusting for the losses of the broker/dealer sector.

Main Calculations

The total trading assets of the industry are $2601bn in November 2007, implying that the rest of the broker/dealer sector is holding trading assets of $1456bn at that time.

Low Scenario (Extrapolation based on Goldman Sachs' net sale): Goldman Sachs had 20.5% of trading assets as credit/mortgage related assets and these assets dropped by 11.7% (as percentage of trading assets in Q4 2007) from Q4 2007 to Q1 2009. Thus we estimate that the other five firms must be holding $317bn ($147bn) of credit/mortgage related assets in Q4 2007 (Q1 2009) under this scenario. Given the 7% rate of repayment on existing assets, the sale by the other five firms (before accounting for losses) is $148bn. Therefore the total sale for the broker/dealer sector is $304bn = $148bn+$156bn under this Low Scenario. Finally, from Table 3, we note that the sector lost $100bn on mortgage/credit assets, implying a net sale of $204bn.

Medium Scenario (Extrapolation based on the average of the three firms' net sale): As a group, the three firms had 31.7% of trading assets as credit/mortgage related assets and these assets dropped by 15.8% (as percentage of the trading assets in Q4 2007) from Q4 2007 to Q1

[28] After acquired by Bank of America the information of investment securities is at Note 7.

2009. We carry out the same calculation as in Low Scenario and find that the net sale is $254bn in this case.

Upper Scenario (Extrapolation based on Merrill Lynch's net sale): Merrill Lynch had 38.5% of trading assets as credit/mortgage related assets and these assets dropped by 20% (as percentage of trading assets in Q4 2007) from Q4 2007 to Q1 2009. We carry out the same calculation as above to find that the net sale is $307bn.

Insurance Companies

Data Sources and Preliminaries

The data source for the insurance sector is their SEC filings. Similar to the broker/dealer sector, the Flow of Funds data do not give detailed enough breakdown on the assets so that we are not able construct a reliable estimate of the credit/mortgage related assets by the insurance industry.

We choose the eight largest insurance companies listed in Table 8 and examine their holdings of mortgage and other ABS as reported in their SEC filings.[29] These eight insurance companies collectively have total assets of $2,136bn as of Q4 2007, which accounts for about 34% of the insurance sector with asset size of $6,365bn (From the Flow of Funds, the total assets of the insurance sector are $6,365bn as of Q4 2007 (including both property-casualty insurance companies, L116, and life insurance companies, L117)). Our methodology is to extrapolate these eight firms to the rest of the insurance sector.

Main Calculations

From Table 8, the sale of credit/mortgage related assets, before accounting for losses, is $152bn = $279bn x (100%-7%)-$107bn. The rest of the insurance sector has a total asset of $4,229bn.

Low Scenario: Extrapolation based on three firms: Berkshire, Travelers, and Liberty Mutual, which have the smallest shrinkage of toxic assets. These three companies have 5.7% of assets as credit/mortgage related assets and the credit/mortgage related assets drop by 0.8% (as percentage of assets in Q4 2007) from Q4 2007 to Q1 2009. Thus we estimate that the rest of the insurance sector holds $241bn ($207bn) of credit/mortgage related assets in Q4 2007 (Q1 2009). Given the 7% rate of repayment on assets, the sale of credit/mortgage related assets by the other firms in the insurance sector (before accounting for losses) is $17bn. Therefore the total sale for the insurance sector is $169bn = $152bn+$17bn. Finally, as reported in Table 3, we

[29] Liberty mutual is not a publically listed company therefore does not have SEC filings. We obtain its annual reports from their website.

note that they have lost $207bn on mortgage/credit assets, implying a net purchase of roughly $38bn.

Medium Scenario: Extrapolation based all seven firms in Table 7 excluding AIG. These seven insurers have 8.9% of assets as credit/mortgage related assets these assets drop by 3.1% (as percentage of assets in Q4 2007) from Q4 2007 to Q1 2009. We carry out the same computation as in the Low Scenario above and find that the net sale is about $50bn.

Upper Scenario: Extrapolation based on all 8 firms including AIG. Including AIG, these eight insurers have 13.1% of assets as credit/mortgage related assets and these assets drop by 8.1% (as percentage of assets in Q4 2007) from Q4 2007 to Q1 2009. We carry out the same computations as in the two scenarios above and find that the net sale is about $247bn.

Commercial Banks

Data Sources and Preliminaries

The data is from the Flow of Funds Report by the Federal Reserve and Call Reports. We do not have to rely on the commercial banks' SEC filings as the these two data sources provide us a fairly accurate read on the holdings of credit/mortgage related assets in contrast to the broker/dealer and insurance sectors.

Main Calculations

From Table 10, the purchase of credit/mortgage related assets, before accounting for losses, is $231bn=$1,774bn-$1,659bn x (100%-7%).

Upper Scenario: Assign the entire total write-downs and losses of $500bn to the credit/mortgage related assets. Then the net purchase is $731bn**.**

Medium Scenario: Assign a fraction of the losses to the security portfolio, based on the IMF Global Financial Stability report which estimates that the banking sector would eventually suffer losses/write-downs of $600bn on loans and $1002bn on security holdings. Using this ratio of 1002/1602, we assign $313bn of losses to the security holdings. The net purchase is $544bn in this case.

Low Scenario: Assign losses based on assumptions about loss rates on the specific assets in banks' portfolios. Banks hold $1192 in Agency-backed MBS and $467bn in privately issued securitized assets. Most of the future losses are likely arise from the privately issued securities. The IMF Global Financial Stability Report (October 2008) reports estimated losses on the outstanding stock of ABS and ABS CDOs to be about 33%. They report loss rates on CMBS of 17%. Taking these numbers as representative of losses on private securitized assets, we

assume that these securities fall in value by 25% between Q4 2007 and Q1 2009. Then, the losses on the private sector assets total $117bn. We further assume that Agency-backed MBS also fall in value by 5%, as spreads in this market widen by about 1% over the period we are interested in (see Krishnamurthy, 2010). Taken together, the total loss estimate is $176bn. Therefore the net purchase is $407bn.