Why were there fire sales of mortgage-backed securities by financial institutions during the financial crisis?

by

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Abstract

Much attention has been paid to the large decreases in value of non-agency residential mortgage-backed securities (RMBS) during the financial crisis. Many observers have argued that the fall in prices was partly caused by fire sales. However, the view that financial institutions with diversified asset portfolios engaged in forced sales of illiquid RMBS is questionable as these institutions presumably could have sold more liquid assets if forced to sell assets. In this paper, we provide a theory for why financial institutions with diversified portfolios would engage in fire sales and find support for it using a unique data set of RMBS transactions for insurance companies. We show that risk-sensitive capital requirements, together with mark-to-market accounting, can cause capital-constrained financial institutions to engage in fire sales of stressed securities because the increased risk can make it too expensive to hold such securities. We also find that RMBS prices behaved as predicted in the presence of fire sales. We document evidence of price reversals after the crisis; that, controlling for mortgage quality, cross-sectional price volatility increased sharply during the crisis and fell again afterwards; and that natural buyers in the RMBS market pulled back during the crisis.

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In most accounts of the credit crisis by economists (e.g., Brunnermeier (2009)) or policymakers (e.g, Bernanke (2012)), fire sales of financial assets are described as the accelerant that helped transform a real estate crisis into a systemic crisis that threatened to cause the collapse of the financial system. Many policy interventions during the crisis were designed to decrease the risk of fire sales (Bernanke (2012)). Policy recommendations by economists on ways to improve regulations to decrease systemic risk after the crisis focused heavily on ways to decrease the risk of fire sales (e.g., French et al. (2009)). Throughout the crisis, a main area of concern about fire sales had to do with the impact of such sales on the value of private label residential mortgage-backed securities (RMBS).[1] These securities, which included securities backed by subprime and Alt-A loans, were held in large quantities by financial institutions so that sharp decreases in their value weakened such institutions, making the crisis worse. A recent account of the crisis blames fire-sale prices of such securities, together with mark-to-market accounting, for weakening the balance sheets of financial institutions, which led to a rash of other problems during the crisis, including runs on some institutions and reduced lending at others.[2]

This paper investigates two important questions related to fire sales. First, we formulate a new theory of fire sales at financial institutions where the incentive for firms to sell securities at fire-sale prices is due to the existence of risk-sensitive capital requirements. We test that theory using RMBS transactions during the financial crisis. Second we evaluate empirically whether fire sales existed on a broad basis in the RMBS market during the financial crisis and find the hallmarks of a market with fire sales. That is, we find evidence of price reversals in the RMBS market, heightened volatility in pricing errors during the crisis, and sidelined natural buyers, suggesting that fire sales were a prominent feature of the market.

The existence of fire sales in financial assets traded by large financial institutions represents something of a puzzle. There is even skepticism that such sales by financial institutions occurred at all (see Boyson, Helwege, and Jindra (2012, 2013)). When a financial institution has to sell assets due to high leverage, or for any related reason, it would seem natural for it to sell the most liquid assets. In contrast to specialized hedge funds, banks and insurance companies typically have large portfolios of securities, so that if they become too highly levered it would seem that they would not have to engage in fire sales of illiquid

securities. However, financial institutions such as banks and insurance companies have risk-sensitive capital requirements. We demonstrate that, with such capital requirements, financial institutions that become capital constrained have strong incentives to sell securities that have become substantially more risky and to do so at prices materially below fundamental value. Our empirical evidence strongly supports the view that risk-sensitive capital requirements can lead to fire sales.

Shleifer and Vishny (2011) were the first to raise the question of whether capital requirements played a role in fire sales in the RMBS market. The capital requirement mechanism is not dissimilar from the role that leverage can play in fire sales of real assets, also proposed by Shleifer and Vishny (1992). The capital requirement mechanism works as follows. Financial institutions are subject to capital requirements. Capital requirements can simply be a percentage of a firm's assets, a capital requirement that is typically called a leverage ratio, or they can be a function of the risk of these assets. We call the latter capital requirements risk-sensitive capital requirements. The Basel Accord of 1988 introduced risk-sensitive capital requirements so that these requirements have been a critical component of banking regulation worldwide. Insurance companies in the U.S. are also subject to risk-sensitive capital requirements. With a leverage ratio, any sale of assets whose proceeds are used to repay debt will decrease a financial institution's leverage. With such a capital requirement, a financial institution generally wants to sell assets that have the lowest selling cost, i.e., assets where the sale involves the smallest discount from fundamentals. The selling decision is considerably more complicated with risk-sensitive capital requirements. With such requirements, a high risk asset requires, potentially, dramatically more capital than a low risk asset. As discussed later, the riskiest securities could require more than fifty times the amount of capital required by AAA-rated securities.[3] Even though low risk assets tend to be more liquid, selling such assets may have little impact on a financial institution's ability to meet capital requirements in contrast to the sale of high risk assets. Hence, a financial institution may be better off, if it faces capital constraints, to sell high risk assets, even at fire-sale prices.

Though there is no data for RMBS trades of banks, there is data for insurance companies. We are therefore able to test our theory for insurance companies. We show that capital-constrained insurance

companies did sell RMBS at lower values, controlling for fundamentals, during the crisis than insurance companies that were not constrained. Our estimates indicate fire-sale discounts in the range of 10 to 12%, depending on the specification. A key issue in our tests is that a company could be forced to sell because it made poor investments, so that it has low quality securities that sell for less because their quality is poor. Hence, the fact that an insurance company is constrained with respect to regulatory capital could just be a proxy for unobservable characteristics of the firm's assets. To avoid a bias, we use an exogenous proxy for whether an insurance company is constrained that is uncorrelated with portfolio choices. An insurance company's operating cash flow is not affected by its portfolio losses. Therefore, we proxy for whether an insurance company is constrained with respect to regulatory capital with whether it made operating losses. Using this estimation strategy, we find strong evidence that capital-constrained insurance companies sold RMBS at prices lower than fundamentals.

There has been much debate about whether fair value accounting standards made the impact of fire sales worse.[4] A widely-held view, summarized for instance in the Economist's account of the crisis, is that fire sales directly impacted the balance sheets of financial institutions because of mark-to-market accounting and hence caused them to record immediate losses. Our dataset is ideally suited to address that issue because different types of insurance firms were subject to different accounting regimes. At the height of the crisis, for purposes of computing regulatory capital, P&C insurance companies had to use fair value for securities that had lost a substantial amount of value but life insurance companies were not subject to such strict fair value accounting. We show that there were fire sales of capital-constrained firms for P&C insurance companies but not for life insurance companies during this period. Further, at the start of 2009, the accounting regime for life insurance companies was anticipated to become the same as the one for P&C insurance companies. Strikingly, in 2009, capital-constrained life insurance companies engaged in fire sales in a manner similar to P&C insurance companies.

The forced sales that we identify among insurance companies are evidence that fire sales may have happened. But, the forced sales we identify may simply be one-off transactions taking place at lower prices because of greater price impact effects due to illiquidity. In order to distinguish traditional price pressure

effects from a market-wide impact of fire sales we investigate whether the RMBS market exhibited characteristics that are associated with fire sales (Shleifer and Vishny (2009)). If knowledgeable investors have capital so that they can exploit discrepancies between market prices and fundamental value, we would expect them to bid for assets so that they would sell at fundamental value. Consequently, for fire sales to take place, natural purchasers must have exited the market. More specifically, investors who would normally bid on the assets sold have to be on the sidelines. These investors are the natural purchasers who have developed the ability to assess the securities being sold. When natural buyers are on the sidelines, investors who bid for the assets are less knowledgeable about them and do not have a natural demand for them. Therefore, these investors will only buy them if they sell at enough of a discount. With investors most knowledgeable about a class of securities sidelined, trade prices for these securities should vary considerably, after accounting for fundamentals, as there would only be weak forces pushing prices back to fundamentals in a market that lacks transparency such as the market for RMBS. Finally, when investors who can exploit differences between fundamentals and market values come back to the market, prices should start reverting to fundamental values. Consequently, we would expect broad market price reversals when there are fire sales, namely abnormal drops in prices relative to fundamentals caused by fire sales followed by abnormal price increases as the conditions that led to fire sales disappear. While reversals do not uniquely establish the existence of a fire sale, they necessarily occur around a fire sale.

A significant difficulty in studying fire sales of RMBS is the lack of data. These securities do not trade on organized markets. Further, in contrast to corporate bonds, trades of RMBS did not have to be reported to a central registry during the crisis, so that there was no post-trade transparency.[5] For our research, this means that there is no comprehensive database of trades of RMBS. Among financial institutions, only one type of firm had to report individual trades of RMBS to regulators, namely insurance companies.[6] In this paper, we use the trades of insurance companies to investigate fire sales in the RMBS market. Though the data is not comprehensive, it is extremely reliable since it is data that the insurance companies use for their accounting and for their reports to regulators. Using that data, we find strong evidence for the indicators of fire sales highlighted in Shleifer and Vishny (2009). Specifically, controlling for fundamentals, which in

this case include mortgage-level data, we find that prices of RMBS securities fell sharply during the crisis but visibly bounced back after the crisis. In other words, there is evidence of price reversals. We find that reversals in prices are even stronger when they are rebounding off the low transactions prices of constrained sellers. We also find that, even when controlling for fundamentals, the cross-sectional standard deviation of prices increased dramatically during the crisis. Finally, among insurance companies, we show that the companies most active in the RMBS market pulled back during the crisis. In other words, the most knowledgeable investors moved to the sidelines.

The paper proceeds as follows. In Section 1, we develop our hypotheses further and review the related literature. In Section 2, we present our data. In Section 3, we show that financial firms had an economic incentive to sell RMBS (forced sales) even at potential fire-sale prices. We show that the propensity to sell RMBS in our sample relates to a firm's capital position and accounting regime. We also document the price impact of forced sales. In Section 4, we investigate the broader market for RMBS and find that it exhibits three important indicators of fire sales, i.e., price reversals, increased unexplained price variability, and natural buyers being out of the market. We conclude in Section 5.

Section 1: Hypothesis development and review of the literature

In this section, we first review in more detail existing theories of fire sales. We then turn to the role of capital requirements and accounting in forcing firms to sell assets. Lastly, we review existing empirical evidence.

Section 1.1 Theories of fire sales

Theories of fire sales describe the conditions under which forced sales occur and commonly contain two important elements: a mechanism by which a forced sale is triggered and a market environment which leads to a dislocation in prices. To date, the literature has argued that leverage and, more specifically, collateralized lending can lead to the forced sale of assets (Shleifer and Vishny (1992, 1997, 2009)). When debt is collateralized by a physical asset and the asset fails to generate the expected cash flows, the optimal contract calls for the sale of the asset.[7] Consistent with this theory, empirical papers have documented the

forced sale of physical assets used as collateral for loans. For example, Pulvino (1998) documents that distressed airlines sold airplanes at substantially discounted prices. Collateralized lending also plays a substantial role in the forced sale of financial assets (see Brunnermeier and Pedersen (2009)). As the value of an asset financed through collateralized lending falls, margin calls force the borrower to either provide more equity or to sell some of the holdings of the asset. Throughout the crisis, margin requirements increased (see Gorton and Metrick (2012)), forcing borrowers to sell assets to meet margin requirements or to provide more equity. As shown by Coval and Stafford (2007), forced sales of assets can also occur when investors in an investment vehicle redeem their holdings.

Though much of the literature on fire sales has focused on collateralized borrowing, regulatory capital requirements can also lead to forced sales for financial institutions. A financial institution can become excessively levered because of adverse shocks. An excessively levered financial institution can meet its capital requirements by selling assets or raising capital. Typically, raising equity capital in the midst of a crisis is difficult, if not impossible, because of the existence of a significant debt overhang. Instead, financial institutions try to restore their capital ratios by selling assets and using the proceeds to pay back debt. With a leverage ratio requirement, any asset sale helps meet the capital requirement by allowing the financial institution to decrease its debt using the proceeds of the asset sale. Consequently, a financial institution would want to sell assets that have low selling costs – i.e., the proceeds are closest to fundamentals.[8] Generally, we would expect sales of assets that trade in well-functioning, highly liquid markets to have the lowest selling costs, so that as long as a financial institution has assets to sell in well-functioning highly liquid markets, fire sales are unlikely. With risk sensitive capital requirements, selling the riskiest assets is the fastest way for a financial institution to meet its capital requirement as these assets have the highest capital requirements. However, the riskiest assets may be assets that trade in dislocated markets, so that a financial institution may have to sell the riskiest assets at fire-sale prices. Because selling the riskiest assets relaxes capital constraints faster, it may still be worthwhile for a financial institution to sell such assets even if it has to sell them at a discount relative to fundamentals. We will present an analysis of the mechanism

whereby capital requirements and fair value accounting rules may combine to create an incentive to sell illiquid distressed securities at fire-sale prices (capital requirement forced sale hypothesis).

A forced sale does not have to take place at prices below fundamental values. In well-functioning, liquid markets, physical or financial assets should sell at prices that reflect their best use. While there may be transitory price pressure effects due to imperfect liquidity, price dislocation may be security specific and reverse quickly.[9] However, in periods of distress for the most natural purchasers of a class of assets, fire-sale prices can occur because the assets have to be bought by buyers who are not natural purchasers of these assets (Shleifer and Vishny (1992)).[10] For instance, in the case of financial assets, the investors who buy may lack the knowledge of these assets that natural buyers would have or may find the payoffs of these assets riskier within their portfolios than natural buyers would. In the case of physical assets, the most natural buyers of an asset might be defined as industry specialists. Industry specialists operate in the same industry as the asset-selling institution and are thus in a position to adequately value and utilize the asset being offered. Industry specialists can put the asset to its first-best use, and pay accordingly. If potential buyers who are industry specialists are constrained on account of financial distress, the first-best use of the asset is not an option. Eventual purchasers of the asset will pay prices below those reflecting the asset's first-best use.

In the case of financial assets, traditional models in finance rely on arbitrageurs to keep asset prices closely aligned with fundamentals. Thus, when arbitrageurs themselves become constrained, rendering them unable to correct mispricings, prices can become more dislocated from fundamentals.[11] Typically, arbitrageurs use collateralized lending. As this lending becomes harder to obtain, they become less able to provide liquidity and correct mispricings. During the crisis, collateralized lending became harder to obtain as many securities that were initially considered to be low risk became much riskier as the crisis evolved. Mitchell and Pulvino (2012) provide empirical evidence of this mechanism at play. Unable to finance their positions during the 2008 financial crisis, hedge funds found it much more difficult to perform their traditional role of taking advantage of mispricings through relative value trades.

Section 1.2 Capital requirements and fire sales

The extent to which capital requirements can lead to fire sales depends very much on how changes in the value of assets affects a firm's capital requirements. If assets are not written down as they lose value, or become impaired, a firm's capital is not affected by fair value losses and hence the firm keeps meeting its capital requirements even if the true value of the assets falls. In such a situation, selling assets whose fair market value has plummeted can be costly because the sale forces the firm to recognize losses that, although they occurred earlier, were not recognized when they occurred. However, if assets are written down as their fair value falls, so that fair value accounting is used, an institution that had enough capital before the write-downs may not have enough capital after the write-downs and hence may be forced to take actions to become compliant with capital requirements. With U.S. regulations, whether securities held for sale are marked down for the purpose of the computation of risk-based capital (RBC) ratios depends crucially on the other-than-temporary-impairment guidelines in the relevant statutory accounting rules governing a financial institution.

If assets are not valued on the balance sheet at fair value and if fair value losses have not passed through earnings, selling assets that have lost considerable value is extremely costly for a financial institution in terms of its RBC ratio as the loss realized upon the sale relative to the value at which the asset is on the balance sheet goes through earnings and comes as a deduction of capital. Insurance companies held their assets on the balance sheet at amortized cost. However, under some circumstances, assets held at amortized cost must be marked down to fair value when they suffer from an other than temporary impairment and the loss has to pass through earnings. With fair value statutory accounting treatment, a financial institution does not postpone the realization of losses by postponing the sale of an asset that has suffered fair value losses.[12] Having recognized the fair value loss, the sale decision of the financial institution simply depends on the comparison of the increased risk charge associated with holding the security in comparison to the possible fire sale discount from selling the security. Absent the fair value treatment, any reduction in risk charge associated with the sale of a downgraded RMBS must be larger than the capital loss from that sale in order for there to be an incentive to sell the asset.

During the crisis, fair value accounting rules were relaxed and the stock market reacted favorably to that relaxation (see Laux (2012)). However, in the insurance industry, there was also a change towards broadening the implementation of fair value statutory accounting rules. This change creates another opportunity to identify the factors influencing RMBS sales by insurance companies. Prior to 2009, P&C insurance companies were required to use fair value accounting for RMBS. In contrast, life insurance companies were allowed to use historical cost accounting for RMBS and were only required to use mark-to-market accounting for NAIC level 5 or 6 securities.[13] Effective for the 2009 reporting year, the National Association of Insurance Commissioners (NAIC) modified SSAP 43 and issued SSAP 43R requiring fair value treatment of asset-backed securities for both life and P&C insurance companies. During 2009, life insurance companies could therefore expect to have the same fair value treatment for asset-backed securities as P&C companies.

While fair value treatment was expected for 2009, the impact on capital was not resolved until late in the year. Ultimately, fair value was implemented with a reduction in capital requirements, which became apparent in the last quarter of 2009. Becker and Opp (2013) describe the reduction in capital that the new rule allowed when securities were marked to market. Essentially, the capital requirement became a function of realized losses relative to expected losses as calculated by a model developed by PIMCO, as opposed to basing capital requirements on credit ratings. A security marked to fair value could have a value close to expected losses, so that its capital requirement might have been small even though it had a low credit rating. The change in benchmarking risk-based capital off the PIMCO model in place of credit ratings was announced during the 4th quarter of 2009 and implemented late in the 4th quarter 2009. This change strongly reduced the impact of fair value adjustments on capital requirements for life insurance companies.

Thus, we would expect the anticipation of mark-to-market requirements and the existing ratings-based RBC rules to manifest itself in the observed selling behavior of life firms during 2009 until the new rule became clear. In summary, we expect the capital requirement forced sale hypothesis to have an effect for life companies between Q1 2009 and Q3 2009 and P&C companies during the entire crisis period, which we define as Q3 2007 through Q3 2009.

Section 1.3 Capital Requirements for Insurance Companies

Capital regulations for insurance companies are based on a system of risk-based capital ratio calculations where capital is compared to an authorized control-level risk-based capital to determine adequacy. If the ratio of capital to authorized control-level risk-based capital (RBC ratio) falls below two, regulatory intervention is required. This is analogous to the regulatory regimes for other financial firms. Comparisons of capital regulations between banking, securities firms, and insurance capital adequacy calculations are provided by Herring and Schuermann (2005).

For insurance companies, as for banks, capital charges increase sharply as asset quality falls below investment grade. For an insurance company, the capital charge on a CCC-rated bond is over fifty times greater than the capital charge on a AAA-rated bond. Consequently, a firm in capital distress can get fifty times more capital relief by selling low credit quality assets than by selling an equivalent amount of more liquid, highly-rated assets. This difference in capital requirements between low credit quality and high credit quality assets means that an insurance company whose RBC ratio might become too low may be better off selling low credit quality assets at fire-sale prices rather than selling a larger amount of high credit quality assets at more advantageous prices. The Appendix provides a detailed numerical example that illustrates the capital requirements and accounting mechanism at play.

Section 1.4 Hypotheses

Our theory of fire sales driven by capital requirements predicts that capital-constrained insurance companies that had to use fair value statutory accounting engaged in fire sales, while insurance companies that were not capital-constrained or that were capital-constrained but not subject to fair value accounting did not engage in fire sales (capital requirement fire sale hypothesis). Further, if fire sales of RMBS took place, we expect price reversals. Price reversals should occur if natural purchasers and/or arbitrageurs were not present to keep prices close to fundamentals. Hence, price declines during the crisis followed by a partial reversal after the crisis is consistent with fire sales (reversal hypothesis). With the lack of natural purchasers

and/or arbitrageurs, the forces that drive prices towards fundamentals are missing. As a result, we expect prices that are affected by fire sales to differ across similar assets because of the lack of natural buyers or arbitrageurs. It follows that there should be variation in prices that is not accounted for by fundamentals (idiosyncratic variation hypothesis). Finally, we should see evidence that natural purchasers were sidelined during the crisis (sidelined natural purchasers hypothesis).

Section 1.5. Related literature

This paper is related to two recent papers also investigating capital requirements and fire sales. Ellul, Jotikasthira, and Lundblad (2011) document forced sales of corporate bonds by insurance companies because of the downgrading of bonds to non-investment grade ratings between 2001 and 2005. They show that such forced sales have an adverse transitory impact when made by firms that have weaker capital positions. A second paper by Ellul, Jotikasthira, Lundblad, and Wang (2012) investigates the differences between the accounting practices of P&C firms relative to life insurance companies. The authors document that fair value accounting motivates higher rates of selling of asset-backed securities (ABS) among P&C firms, whereas historical cost accounting for life insurance firms (hereafter called 'life firms') motivates them to hold downgraded asset-backed securities, selling corporate bonds instead. The "gains trading" of corporate bonds can induce fire sales in the corporate bond market. While similar in motivation to these papers, our work is focused on the market for RMBS, which played a critical role in the recent crisis, and on direct examination of all the main indicia that are associated with fire sales. Our work also uses a substantially different empirical strategy in identifying the effects of capital requirements and accounting rules on fire sales. One key difference in empirical strategies is our focus on the specific transaction prices of individual securities.

Two other papers explore implications of capital requirements for insurance companies during the crisis. Koijen and Yogo (2013) present striking evidence that capital requirements can lead insurance companies to sell products at an economic loss to relax risk-based capital constraints. They find that life insurance companies were willing to sell annuities at a substantial economic loss to relax these constraints.

Becker and Ott (2013), discussed earlier, explore the implications of the change in regulations surrounding risk-based capital requirements for life insurance companies in the last quarter of 2009.

Other related papers examining the investment behavior of insurance companies include Ambrose, Cai, and Helwege (2012), Becker and Ivashina (2012), and Manconi, Massa, and Yasuda (2011). Ambrose et. al. (2011) examine regulatory-induced trades of insurance companies and conclude that a widespread selling of bonds does not necessarily lead to pressure on prices. Rather, observed price declines occur on account of information effects. Becker and Ivashina (2012) find that capital requirements provide incentives for insurance companies to "reach for yield" in their security selection. Finally, Manconi, Massa, and Yasuda (2011) find that the yield spreads of bonds increased more for bonds whose pre-crisis holders had more investments in structured finance. The explanation is that investors who held more structured finance securities had to rebalance their portfolios as they made losses on these securities, leading them to sell bonds that were more liquid. These sales led the prices of these bonds to become depressed relative to the prices of other bonds. In their study, they consider both insurance companies and mutual funds.

Finally, our paper contributes to a growing literature focused on the costs and benefits of fair value accounting and of how fair value accounting contributed to the crisis. An early theoretical paper in this literature, by Plantin, Sapra, and Shin (2008), shows how fair value accounting can lead to a vicious cycle of sales for levered institutions. Heaton, Lucas, and McDonald (2010) build a model showing that the interaction between fair value accounting and capital requirements can lead to inefficient bank liquidations because of time variation in aggregate discount rates. Laux and Leuz (2009) and Laux (2012) review much of the literature on the topic. Laux (2012) concludes that "there is still no evidence that fair value accounting caused widespread fire sales of assets or contagion." Some papers (e.g., Shaffer (2010)) focus on the link between fair value and bank regulatory capital. However, these papers are more concerned about the impact of fair value losses on bank capital rather than about how capital-constrained banks are pushed into fire sales. Baderscher et al. (2012) provide evidence of fair value charges for the largest bank holding companies and show that, for 2007-2008, the bulk of these charges were incurred in the last two quarters of 2008. They

also show that sales of RMBS are correlated with fair value charges, but Laux (2012) argues that such a correlation can have multiple causes.

Section 2: Data

In this section, we describe how we construct our sample, the data we use to control for the characteristics of RMBS, and provide summary statistics.

Section 2.1 Sample Construction

Our empirical tests analyze open market transactions of RMBS made by insurance companies between the years 2006 and 2012, with a particular focus on transactions that occurred during the crisis. We explain variation in RMBS transaction prices as a function of the attributes of the mortgage collateral and of insurance companies. This requires the merging of three unique data sets on RMBS transactions, mortgage collateral attributes, and insurance company attributes. We briefly describe each database and how we merge the data.

RMBS transaction data are made available by Thomson Reuters EMaxx services, which compiles all of the publicly reported transactions of P&C and life insurance companies from regulatory filings and produces a standardized bond transaction file. Data fields include transaction date, transaction price, bond CUSIP, whether the transaction was a purchase or sale, the name of the insurance company involved in the transaction, the transaction broker, transaction volume (more than one investor can own a portion of the bond), and the bond credit rating at the time of the transaction. To account for unobserved features of each RMBS (e.g., seniority in the capital structure of a deal, performance triggers, differences in pre-payment treatment, and other unobserved contractual features), we limit the sample to repeat-sales transactions of the same RMBS and measure changes in RMBS prices from the first transaction to the second. A repeat-sale sample has the virtue of implicitly controlling for unobserved features that could impact the price of a RMBS.

We match the universe of insurance company RMBS transactions to a database of mortgage collateral attributes produced by CoreLogic. A non-agency RMBS is collateralized by over 5,000 individual non-agency loans, on average.[14] Loan-level attribute data are rolled up to the deal-level using loan sizes as weights. For example, when controlling for deal-level FICO scores, the deal-level measure represents the loan-weighted FICO score of the individual underlying mortgages. Importantly, our collateral attribute data is dynamic, allowing for the real-time measurement of the mortgage attributes at the time of each transaction, including the cumulative default rate on the pool of mortgages at the time of the transaction. Other collateral attributes aggregated to the deal level include mortgage rates, FICOs, and combined loan-to-value ratios (LTVs). We also calculate the percentage of collateral with adjustable rates (ARMs), mortgages supporting owner-occupied homes, no or low documentation loans, and the percent that represent refinancing mortgages. We control for deal-level rates of cumulative house price appreciation by matching ZIP-code level house price indexes to the ZIP code of each mortgage.[15]

We rely on insurance company attribute data from AM Best and the National Association of Insurance Commissioners (NAIC). AM Best specializes in the production of insurance company analytics, including data on annual levels of operating cash flow. The NAIC provides data on regulatory capital filings as well as income statement and balance sheet data. We match insurance company attribute data from NAIC and AM Best to the RMBS transaction file by insurance company name. We drop extreme outliers in RMBS prices and in the operating cash flow of insurance companies at the 1% and 99% levels to reduce the influence of outliers in the data.[16] Implementing a repeat-transaction criterion reduces our final sample to 14,172 unique repeat transactions from 1,014 life and P&C insurance companies over the period January 2006 to December 2012.

Section 2.2 Control Variables

Our empirical tests control for fundamental attributes of RMBS which should impact RMBS prices. One of the primary determinants of RMBS performance is the default rate on the underlying pool of mortgages. Our data allow for the calculation of real-time collateral default rates. We focus on the reported collateral default rate in the month prior to the observed transaction so as to ensure that the default rate used

in our estimation reflects the collateral default rate observed by market participants at the time of a transaction.

An issue that deserves special consideration is our choice to control directly for the collateral default rate as opposed to bond credit ratings, especially given that capital requirements are tied to credit ratings. The reasons for our approach are straightforward. First, insurance companies are concerned about what the rating will be at the time they compute their RBC ratio, which occurs at the end of the calendar year.[17] We believe that our approach, because of its greater timeliness, offers a better forecast of ratings for insurance companies. Second, our approach allows for greater granularity in assessing the credit quality than do credit ratings because our approach uses continuous variables. Third, we are able to update our estimates of credit quality monthly using the most up-to-date information. It is commonly known that ratings are not designed to reflect real-time assessments as rating agencies are also concerned about the stability of ratings. Further, for practical reasons, rating agencies could not update ratings monthly even if they wanted to reflect the most current monthly information since doing so would involve making changes to tens of thousands of ratings monthly for the major credit rating agencies.

Two pieces of data show that these considerations are important. First, during our sample period, Moody's and S&P ratings differ, often markedly, for some deals. Such material differences could easily arise because of differences in the timing of rating updates. Second, there is considerable variation in prices within rating buckets during our sample period, which again is consistent with ratings being more up-to-date for some deals than others. Because of these considerations, we believe that our approach provides a more detailed and up-to-date assessment of credit quality than using credit ratings. We repeat our primary tests using credit ratings. While the results using credit ratings are qualitatively similar to our baseline results, they are not as robust.

Bond prices are also mechanically influenced by interest rates. Over 80% of the RMBS in our sample pay a floating coupon rate, making their value immune to direct changes in interest rates. For the small set of bonds with fixed coupon rates we control for changes in the 5-year Treasury bond rate between the first and second transactions.[18] Our results are robust to the exclusion of fixed-coupon RMBS, but we include

them in our reported tables so as to maximize our sample size. Other control variables that we include in the regressions are variables commonly used to predict future loan defaults.[19]

Section 2.3 Summary statistics

Table 1 reports summary statistics on the quarterly attributes of our estimation sample. Each observation in the table represents the attributes associated with the second transaction in a given repeat-transaction pair. Over the full sample period the average bond experienced a 0.6% decline in price from the first transaction to the second, but price declines were much more dramatic during the financial crisis. Prices began declining most precipitously during the third quarter of 2007 and continued a steady decline through the third quarter of 2009, but experienced a slight rebound thereafter. In our formal regressions, we single out the Q3 2007 – Q3 2009 time period as the crisis period because it represents the time when RMBS prices were consistently declining. It also represents the time that P&C and life companies used credit ratings in calculating RBC (though only Q1-Q3 2009 in the case of life companies). The pattern of average price declines documented in the initial columns of Table 1 can be observed visually in Figure 2, which plots the level of non-agency RMBS prices through time. The figure provides stunning visual evidence of the rapid decline in the market value of RMBS throughout the financial crisis. These price declines took place for RMBS that were highly rated at origination. Though not reported in Table 1, 93.3% of the rated RMBS in our repeat sample estimation were rated AAA, AA, or A at the time of the first observed transaction. Default rates on mortgage collateral associated with transactions in Q3 2007 increased from an average of 7.66% to 17.98% by Q3 of 2009. This fact highlights the need for careful identification of the unique impact of capital requirements, as opposed to RMBS fundamentals, in explaining the observed low prices paid for RMBS. Observed RMBS prices were low during the crisis period, but so was the quality of their fundamentals.

Section 3: Forced Sales of RMBS.

In this section, we first estimate the propensity of capital-constrained firms to sell RMBS. Next, we explain how we identify companies that are capital constrained for reasons other than losses on their asset portfolios. Then, we show that capital-constrained insurance companies subject to fair value sold RMBS at lower prices than either insurance companies that were not capital constrained or that were not subject to fair value.

Section 3.1 Estimating the Propensity to Sell RMBS.

In this section, we test whether capital-constrained firms are more likely to sell RMBS. Under our capital requirement fire sale hypothesis, the urgency of obtaining the capital relief that comes with selling a marked-to-market, low-credit-quality asset outweighs the cost of the expected fire-sale discount. As such, we expect that capital constrained firms subject to fair value statutory accounting will be more likely to sell, all else equal.

To test our hypothesis, we estimate a Cox proportional hazard model using a firm-RMBS panel data set. For each unique RMBS purchase observed between 2006-2008, we construct a panel of monthly observations on the attributes of the mortgage collateral supporting the purchased RMBS as well as the attributes of the insurance company that purchased the RMBS. We track the attributes of the RMBS beginning at the date of purchase through time until either we observe the selling of the RMBS by the original purchasing firm or our sample period ends. We begin the panel in 2006 because it is the first year for which we have insurance company data. We end the sample in 2008 to preserve the key difference between P&C and life firms' adherence to mark-to-market accounting in our estimates.

In the proportional hazard estimation, we define "failure" as the sale and "survival" as the retention of a purchased RMBS during the sample period. The conditional nature of the proportional hazard estimation allows us to control for the attributes of RMBS collateral that influence the selling decision through time. Our baseline specification controls for several key measures of the attributes of the RMBS collateral during each month the bond is held in the portfolio. These include the RMBS collateral default rate in the month prior to the transaction as well as the cumulative rate of ZIP code-level house price appreciation for the

mortgage pool since origination. We control for pool-level FICO, combined LTV, the percentage of mortgages that are ARMs, owner occupied, no/low documentation, or refinancing mortgages. We also include calendar-time fixed effects in order to capture unobserved macroeconomic factors that could influence RMBS transactions, though calendar-time fixed effects are highly correlated with deal-level collateral default rates.[20] Standard errors are clustered by month.

Table 2 reports results of the hazard estimation. Column (1) includes both life and P&C firms in the estimation. We create a P&C indicator variable designed to measure the difference between life and P&C firms in the propensity to sell, conditional on the real-time attributes of the RMBS. The estimated coefficient on the P&C indicator is positive and statistically significant, indicating that for a given set of RMBS characteristics – including time held in portfolio – P&C firms are more likely to sell RMBS. In terms of economic significance, the magnitude of the estimated coefficient indicates that at sample-average collateral values, RMBS are predicted to remain in P&C portfolios 5 months less than in life portfolios, all else equal.

The results in Column (1) are consistent with the prediction that P&C firms are more likely to sell RMBS, but the estimation in Column (1) does not clearly identify the role of capital requirements. The difference in selling propensity driving the positive estimate on the P&C indicator could also be attributed to unobservable differences between the two firm types. This includes the possibility that P&C firms could have higher portfolio churn on account of a more frequently changing liability structure compared to life firms or because of more frequent policy redemptions. In an effort to identify the role of capital requirements in the selling decision more directly, we create an indicator variable for firms with below-median RBC ratios in a given year. Under a capital requirement fire sale hypothesis, firms with low levels of RBC ratios would feel a greater urgency to sell RMBS compared to less capital-constrained firms.

In Columns (2) and (4) we split the sample by insurance type and estimate the proportional hazard model where the below-median RBC indicator is the independent variable of interest. Median RBC ratios are measured within insurance company type and within each year of the sample. The results in Column (2) suggest that below-median RBC P&C firms are significantly more likely to sell than above-median

P&C firms, conditional on a given set of RMBS characteristics. Holding RMBS attributes at the P&C sample average, below-median RBC P&C firms were predicted to hold RMBS 6 fewer months than above-median RBC P&C firms. In contrast, the results in Column (4) indicate that the RBC position of life firms has no significant impact on their propensity to sell.

In Columns (3) and (5) we test whether the propensity for below-median RBC firms to sell is different at a given level of collateral default. The capital requirement fire sale hypothesis predicts that the urgency of selling would be higher for poor credit-quality RMBS held by low RBC ratio firms subject to fair value statutory accounting practices. In testing the poor credit-quality aspect of this prediction we create a new variable that measures the interaction of the real-time mortgage collateral default rate with the below-median RBC indicator for the P&C and life samples, respectively. Though the previous estimates control for the average level of real-time credit attributes of the RMBS, the interaction term measures the propensity to sell at a given level of collateral default. For the P&C sample, as reported in Column (3), the estimated coefficient on the key interaction term is not statistically different from zero. In the life sample, as reported in Column (5), the estimate on the key interaction term is also insignificant.

Measuring capital constraints using an above and below-median RBC ratio cutoff could be too imprecise. Regulatory capital constraints will be binding as firms move close to the regulatory boundary, which requires firms to maintain an RBC ratio above two. Empirically, few firms in our sample maintain RBC ratios near the edge of the regulatory boundary of two, preferring instead to maintain a small cushion. This makes it difficult to test whether maintaining an RBC ratio right at the boundary makes firms more likely to sell compared to firms well above the boundary. We do observe some clustering of RBC ratios around four for P&C firms, which represents roughly the 25th percentile in the distribution of RBC ratios. The 25th percentile in the distribution of the RBC ratio for life firms is close to six. In an effort to test the robustness of the results in Table 2 to an above and below-median RBC cutoff, we estimate the selling propensity of firms in the lowest 25th percentile of RBC. In untabulated results, we find that P&C firms with RBC ratios in the lowest 25th percentile are more likely to sell RMBS as compared to P&C firms in

the upper 75th percentile. In contrast, life firms in the lowest 25th RBC ratio percentile are not more likely to sell.

The results from the Cox proportional hazard estimation support two of the key predictions of a capital requirement fire sale hypothesis. First, P&C firms are significantly more likely to sell RMBS than life firms. Second, the likelihood of selling is correlated with the RBC position of P&C firms but not with the RBC position of life firms. These results could be due to a number of differences between P&C and life firms. Thus, we next consider an empirical approach that narrows the focus to RBC and mark-to-market accounting explanations.

Section 3.2 Motivating the Identification Strategy.

While a probability-based estimation strategy has the potential to estimate the likelihood of observing sales, probability-based estimates are not as effective at capturing the urgency to sell. Tests involving market prices are better suited for the estimation of discounts on account of selling urgency. In this section we document pricing patterns that exist in the data and evaluate whether the observed patterns are consistent with the fire sales hypothesis.

Identifying a causal link between low levels of capital at insurance companies and RMBS transactions that occurred below fundamental value is a challenge because omitted variables could bias our pricing estimates. RMBS transactions that appear to occur below fundamental value could be on account of unobserved, poor collateral quality. Poor collateral quality could also be responsible for low levels of capital within a firm if losses on collateral have themselves been responsible for a reduction in a firm's capital. Because of this possibility, we propose a specification designed to disentangle the endogenous relationship between firm capital and RMBS credit quality.

As a starting point, consider a simple, linear model of the following form:

$$Price_{i,t} = \alpha + \beta \cdot Constrained\ Firm\ Indicator_{j,t} + \delta X_{i,t} + \varepsilon_{i,t},$$

where subscripts *i* and *t* represent RMBS *i* transacted at time *t*, subscript *j* represents firm *j*, and *X* represents a matrix of bond fundamentals. *X* includes the full set of RMBS-specific fundamentals described in the data

section. In addition to observable attributes of the collateral, a specification explaining variation in RMBS prices must address other issues. The repeat-transaction criterion implicitly controls for deal-specific features of each RMBS such as seniority in the deal's capital structure and other unobserved contractual features. Despite these sample criteria, omitted variables may still plague the proposed pricing specification. The most obvious concern is that an unobserved attribute of RMBS quality could itself be the cause of an intermediary's constrained capital position. RMBS values are not exogenous to a firm's capital position because an otherwise healthy firm could suffer capital distress on account of the credit attributes of the RMBS portfolio itself. Such an omitted variable bias may make it difficult to determine whether a constrained seller's transaction of an RMBS at a dislocated price is on account of capital expediency or because of unobserved features of RMBS credit quality that cause the firm to sell the RMBS *and* that explain the low trade price.

We propose using negative shocks to a firm's operating cash flow as an exogenous proxy for the capital urgency of a firm. Cash flow from operations essentially represents an insurance company's underwriting income. As such, negative cash flow from operations represents an episode of increased liabilities, triggered most frequently by an increase in insurance claims. Negative cash flow from operations should not be influenced by recognizing losses on RMBS because, in the statutory accounting treatment of insurance companies, investment income does not contribute to cash flow from operations. Because of this, negative operating cash flow should be correlated with firms experiencing capital distress; however, the source of distress is not likely to be correlated with the fundamentals of the RMBS we are trying to evaluate.

The size of operating losses is clearly influenced by the size of the insurance company. As such, we scale operating losses by a firm's 2006 level of capital so that the variable captures some proportion of the contribution or destruction of capital that is attributable to the operating loss. We use the 2006 level of capital because levels of capital in the contemporaneous year of operating losses could be correlated with poor RMBS fundamentals.[21] In evaluating the robustness of our operating-cash-flow-to-2006-capital variable, we also estimate results when scaling operating cash flow by the level of a firm's assets. The results are comparable to those we present in the tables. We use operating cash flow scaled by 2006 capital

as our primary measure because it has a more relevant economic interpretation than operating cash flow scaled by assets. One limitation of the negative operating cash flow proxy is the constraint it places on our sample size. Less than one-third of the repeat transactions in our sample are associated with firms that experienced negative operating cash flow.

As a check on the validity of negative operating cash flow shocks as an exogenous proxy for capital distress, we examine the empirical relationship between year-over-year changes in levels of capital at insurance companies and episodes of negative operating cash flows. In our sample of insurance companies, firms experiencing a negative operating cash flow shock in a given year are associated with statistically significant 9.8% lower levels of capital compared to the previous year, on average. The result is consistent across each of the years in our sample period. In contrast, the average firm in our sample not exposed to a negative cash flow shock experienced a 6.1% increase in capital each year in the sample period.

Section 3.3. RMBS pricing and operating cash flow shocks.

In this section we test the key prediction of our capital requirement fire sales hypothesis, which is that risk-based capital requirements and fair value accounting lead capital-constrained firms to engage in fire sales of RMBS. Our test employs a sample of repeat transaction RMBS where the second transaction occurred between Q3 2007 and Q3 2009. We limit the sample to this time period in order to focus on pricing conditions during the financial crisis when fire-sale conditions were the most prevalent. Our later analysis utilizes the full sample of repeat transactions from 2006 through 2012 to identify price reversals and other pricing patterns consistent with the existence of fire sales.

The use of a repeat sales sample in our estimation requires careful attention to the potential empirical issues it presents. One such challenge is the handling of bid-ask spreads, particularly in an illiquid market. Our dependent variable is calculated as the percent change in the price of an RMBS from the previous transaction to the second transaction. We create a sale indicator variable which is equal to one if the second transaction in a pair of transactions is a sale because we are interested in testing whether the sales of capital constrained firms are statistically different from the sales of non-constrained firms, all else equal. Drawing

inference on fire sales from the coefficient on the sales indicator is potentially difficult because sale prices are expected to be consistently lower because of the bid-ask spread. We overcome this challenge through the interaction of the sale indicator with the operating-cash-flow-to-2006-capital ratio. The interaction term allows for a comparison of sales transactions of firms with various levels of operating cash flow. It is not clear *ex ante* why any bid-ask spread bias of sale transactions would be correlated with the ratio of operating-cash-flow-to-2006-capital of the seller in a given year. Accordingly, we expect the estimated coefficient on the sale, capital-constrained interaction variable to represent a reasonable estimate of the difference in sales between capital constrained and less-constrained firms.[22]

A second issue with a repeat sales approach which deserves attention is the amount of time between each transaction. Though we control for quarter fixed effects, changes in market conditions in the time between two unique transactions would not be captured by simple quarter fixed effects. We control for the number of months from the prior trade as an additional factor that could impact the change in price between two consecutive transactions of the same RMBS. We also interact the number-of-months-from-prior-trade variable with the quarterly time dummies, so as to capture any changing dynamics in the market that could occur in the time between two transactions.

A repeat sales approach also creates the possibility of selection bias in the RMBS that are involved in more than one transaction. We investigate whether selection exists by estimating our tests with a sample that includes any RMBS transaction, not just the second transaction in a repeat transaction pair, that occurred between Q3 2007 and Q3 2009. Our results are robust to this approach, and are economically very similar to those presented in the tables.

The repeat sales sample also influences the specification of our control variables. Rather than controlling for the level of collateral attributes such as collateral default rates, rates of house price appreciation, etc., we control for *changes* in the control variables from the time of the first transaction to the second. The change in collateral attributes should more accurately capture the change in credit quality that might influence observed pricing changes. For example, two unique pairs of repeat transactions might be associated with the same level of collateral default rates at the time of the second transaction, but one

pair of transactions might be associated with a much larger relative change in default rates between the first and second transactions. Fundamentally, we believe the change in the price between the two transactions should reflect the change in collateral attributes, not just the level of attributes at the time of the second transaction.

Finally, the relationship between price changes and the sign of operating cash flow is likely to be asymmetric. A positive operating cash flow of an insurance company in a given year should have little bearing on the capital *urgency* of the firm and thus on the urgency of selling an impaired RMBS. We would expect non-capital constrained firms to be less likely to accept the price discount associated with a "forced" sale transaction. However, a negative operating cash flow situation should be associated with an urgency to sell and the potential willingness to accept a discount to remove the capital requirement associated with an impaired security. In order to capture the potential asymmetry in our estimates, we split the estimation sample into transactions of firms with negative operating cash flow and positive operating cash flow.

Table 3 reports the estimation results of our pricing specification. The dependent variable in each specification is the change in price from the first transaction to the second. Control variables include changes in collateral attributes, changes in market interest rates, the time between the two transactions, quarterly fixed effects, and the interaction of the quarterly fixed effects with the time-between-transactions variable. We cluster standard errors by the second transaction month and by firm. The sample period in Columns (1) and (2) is Q3 2007 through Q3 2009 given that the time period represents the period of declining prices in the RMBS market and the fact that P&C firms were adherent to mark-to-market accounting practices over that whole period. The coefficient of interest in Column (1) is the interaction of the operating-cash-to-2006-capital ratio with the sale indicator. The interaction term is positive, indicating that the sales of firms with larger *negative* operating cash flows are associated with larger price *declines*. The magnitude of the estimate indicates that a one-standard deviation *decline* in the operating-cash-to-2006-capital ratio, from the mean of -0.22 to -0.52, results in an 11.6% price decline. In contrast, the interaction of the sale indicator with the continuous measure of positive operating cash flows, as reported in Column (2), is not significantly different from zero.

Columns (3) and (4) of Table 3 repeat the estimation for the sample of life firms using the Q3 2007 – Q4 2008 sample period in which life firms were not mandated to follow fair value accounting practices. The key interaction term, operating-cash-to-2006-capital*sale-transaction, is not statistically different from zero in the negative or positive operating cash flow samples. This result is consistent with a lack of selling urgency for life firms, given their ability to hold RMBS on the books at historical cost. As a means of identifying the effect of fair value accounting on the urgency of selling, in Columns (5) and (6) we estimate the same specification using a sample of repeat transactions for life firms where the second transaction occurred in Q1 through Q3 of 2009. Given the looming adoption of fair value accounting and the uncertainty around capital impact for life firms within the year 2009, such transactions could reflect the fire-sale characteristics fueled by the combination of fair value accounting and capital requirements. The positive and significant estimate on the operating-cash-to-2006-capital*sale-transaction interaction term indicates the fire-sale mechanism at play in the first three quarters of 2009. Life firms in 2009 that experienced larger negative operating cash flow shocks were involved in RMBS sales that occurred at significant discounts relative to the prior transaction. The estimated coefficient suggests pricing discounts as large as 13.5% for life firms experiencing a one-standard deviation more severe level of negative operating cash flow. By way of comparison, the sales of life firms with positive operating cash flow in 2009 do not demonstrate similar pricing patterns.

The results presented in Table 3 appear consistent with a capital requirement fire sale hypothesis. All else equal, when selling an RMBS, a firm that experienced a larger negative operating cash flow shock sold RMBS at a statistically significant greater decline in price compared to a firm with a less negative operating cash flow shock. One concern with the use of negative operating cash flows as an exogenous proxy for capital distress is the possibility of a "poor management" omitted variable that could impact both operating cash flow and the selection of poor credit-quality RMBS. The change in fire-sale patterns for life companies consistent with the timing of their adherence to fair value statutory accounting, as documented in Table 3, is not consistent with a time invariant "poor management" explanation.

However, despite the consistency of the results with a capital requirement fire sale hypothesis, the results still do not rule out other viable alternatives. Any issue besides capital requirements that impacts an insurance company's need for liquidity could be addressed through the forced sale of securities. For example, life insurance firms may face higher policy redemptions, forcing the firm to liquidate assets at potential fire-sale prices to meet client's liquidity demands. Such a demand for liquidity would affect operating cash flow and could produce results consistent with those documented in Tables 2 and 3. However, we would expect an insurance company with liquidity needs to sell its most liquid securities rather than the ones with the highest capital requirements. Another explanation of the observed empirical patterns focuses on the housing market. RMBS pricing declines and negative cash flow shocks to insurance companies could both occur on account of a shock to regional housing markets. In the following section we propose a specification designed to test a unique aspect of a capital requirement fire sale hypothesis.

Section 3.4. Does the credit quality of the bond influence the magnitude of fire-sale discounts?

Regulatory capital charges increase as the credit quality of assets declines. As detailed in Section 1.3, in the case of insurance companies, assets of the highest credit-quality are assigned a 0.004 RBC net factor while assets of poor-quality (e.g. CCC-rating) are assigned a substantially larger 0.23 RBC net factor. The inverse and non-linear relationship that exists between the credit quality of an asset and the amount of capital that must be held against the asset gives rise to our next test. Price discounts associated with urgent sales should be most severe for the most severely credit-impaired securities.

A test of this hypothesis requires objective measurement of the credit quality of RMBS. As before, we use observable collateral default rates in the month prior to a transaction as our measure of RMBS credit quality. We calculate collateral default rates as being above or below median at the time of the second transaction for each repeat sample pair. The above median default calculation uses the full sample of default rates as of the second transaction. We then create a variable that interacts the operating cash flow variable with the sale indicator and an above-median default indicator. The three-way interaction should measure the marginal pricing difference between the sales of capital constrained firms on high versus low credit-

quality RMBS. As was the case in Table 3, we estimate the regression separately for negative and positive operating cash flow firms and define the crisis period as Q3 2007 through Q3 2009.

Table 4 presents the results of this estimation. We control for the same set of collateral attributes as in previous tables, with the exception of default rates. The above-median default rate indicator serves as a proxy for the level of collateral default rates in this specification. As reported in Column (1), the estimated coefficient on the interaction term operating-cash*sale-transaction*above-median-defaults is positive and statistically significant in the P&C sample. The positive coefficient indicates that sales from firms with larger *negative* shocks to operating cash flow are associated with larger negative bond price changes for high collateral default RMBS compared to low collateral default RMBS. In contrast, Column (2) reports results of the estimation in the negative operating cash sample of life firms between the years 2006-2008. The estimated coefficient on the interaction of interest is not statistically significant, consistent with estimates on life transactions reported in previous tables. Column (3) reports results using the sample of life transactions in the first three quarters of 2009. Consistent with results presented in Table 3, the results documented in Column (3) indicate that the second transaction in a repeat-transaction pair for life firms exhibited fire-sale characteristics in 2009 and that fire-sale discounts were largest on RMBS of the worst credit quality. The existence and magnitude of fire-sale discounts appear to be related to the credit quality of the RMBS, but only for firms subject to fair value statutory accounting.

Taken together, we interpret our results to be consistent with a capital requirement fire sales hypothesis. If an omitted variable were driving these results, such a variable would have to be uniquely correlated with the sales of the worst credit-quality bonds of insurance companies that have experienced a negative shock to operating cash flows but not correlated with the sales of the worst credit-quality bonds of insurance companies with positive operating cash flow. The omitted variable would also have to be correlated only with P&C firms through the full sample period and not life firms except during the first three quarters of 2009. While it is difficult to conclusively rule out all possible alternatives, we cannot identify alternative hypotheses that are consistent with the observed empirical patterns.

Section 4. The RMBS Market and Fire Sales

The forced sale discounts identified in the previous section could be evidence of fire sales in the RMBS market during the crisis. However, an alternative possibility is that the results simply identify microscopic, one-off forced sales of RMBS that cause price pressure, resulting in price discounts. In this section we present broad, macroscopic evidence that indicates the forced sales and resultant pricing discounts identified in the previous section took place in an environment that demonstrates the hallmark signs of fire sales in the broader RMBS market.

In addition to forced sales, Shleifer and Vishny (2011) identify at least three other indicators of fire sales that have been explored in the literature. These are the exit of natural buyers, price reversals, and violations of arbitrage conditions. None of these indicators are individually dispositive in isolation and, in fact, they are interconnected. But, when there is evidence of a mechanism that forces sales, capital requirements in our setting, and the other three indicators, the literature seems to conclude that there is evidence of fire sales. Having found evidence of forced sales associated with fair value accounting rules and capital requirements, we next look for evidence of the other hallmarks of fire sales. In this section, we present evidence of price reversals, of increased idiosyncratic variation, and of natural buyers leaving the market.

Section 4.1. Evidence of Price Reversals

As a starting point, we plot in Figure 2 the average price paid in RMBS transactions over the sample period Jan 2006 through December 2012. Average RMBS transaction prices of originally AAA-rated securities hovered around par value as of Q4 of 2006.[23] Prices began to fall slightly in Q3 of 2007, averaging 96.58 cents on the dollar. Prices plummeted substantially in 2008, averaging 84.20, 82.75, 76.22, and 67.05 in quarters 1, 2, 3, and 4, respectively. Prices fell even further into Q3 of 2009, reaching a low of 66.51. Prices rebounded slightly in Q4 of 2009 and into 2010, reaching an average of 81.56 by Q4 of 2010. Prices remained volatile in 2011 and 2012, but held steady at levels above the lows of 2009, on average.

Evidence of reversals using the level of prices does not account for mortgage characteristics. We now turn to evidence on price reversals that accounts for the influence of mortgage characteristics on price changes. We first show a plot of residuals that arise from a regression of RMBS prices on a set of mortgage collateral fundamentals. In a first stage regression, we estimate variation in observed RMBS prices as a function of one-month lagged default rates, cumulative rates of house price appreciation, mortgage interest rates, FICO, loan-to-value ratios (LTV), the fraction of mortgages with adjustable rates (ARMS), are owner-occupied, provide full income documentation, are refinancings, and the change in the 5-year T-bond rate from the time of origination. We harvest the residuals from this estimation and plot them in Figure 3. The residuals are centered around zero during the period of January 2006 through the third quarter of 2007, then fall substantially during the crisis period, only to revert back to an average of zero during the post-crisis period. Figure 3 demonstrates that, remarkably, the fundamentals of the mortgage collateral explain most of the predictable variation in RMBS prices, except during the crisis. Figure 3 is more compelling when compared against Figure 2 because it demonstrates that although the post-crisis level of prices did not fully recover back to pre-crisis levels – remaining instead around 80 cents on the dollar – the sustained lower level of prices were fully justified by poor collateral fundamentals. The fundamentals regression captures this aspect of RMBS pricing and, thus, the residuals remain centered around zero, even after the crisis. Also, the residual plot clearly demonstrates that prices during the crisis period fell well below values justified by the fundamentals.

Our second piece of evidence of reversals comes in an analysis of changes in RMBS prices using a repeat transaction sample. For each RMBS in our sample that is involved in more than one unique transaction, we calculate the change in price from the first transaction to the second transaction. If an RMBS has N unique transactions, we calculate N-1 unique transaction pairs. Estimating changes in RMBS prices using multiple transactions on the same RMBS allows us to control for unobservable characteristics of RMBS that could influence pricing. Our sample of repeat transaction pairs begins with transactions as of January 2006 and runs through December 2012.

We construct six indicator variables of interest. The first indicator is equal to one for paired-transactions where the first transaction occurred during the crisis and the second occurred after the crisis. Recall that we define the crisis period as Q3 2007 through Q3 2009 as it corresponds to the time period of declining RMBS prices. A second indicator captures paired-transactions where the first transaction occurred pre-crisis and the second transaction was during the crisis. A third indicator captures transaction-pairs where both transactions occurred during the crisis. The fourth indicator is equal to one for transaction pairs where both transactions occurred post-crisis. The fifth indicator captures transaction pairs where the first transaction was pre-crisis and the second was post-crisis. The sixth and final indicator captures transaction pairs where both transactions were pre-crisis and it serves as the omitted category in our analysis. Given that two pre-crisis transaction pairs (sixth and omitted indicator) exhibited virtually no change in price, the coefficients on the remaining transaction pairs essentially represent the average change in price over the relevant transaction period. As in our pricing analysis, we include control variables designed to capture *changes* in collateral quality between the first and second transaction. Because the time-between-transaction indicator variables capture very specific time periods, they are highly correlated with some control variables designed to capture changes in macroeconomic conditions during these same time periods. For this reason we omit the change in house price control as well as changes in the five-year T-bond rate, mortgage rates, and the time between transactions controls.

Table 5 reports the results of a regression where changes in RMBS prices are regressed on the time period indicators and measures of changes in mortgage fundamentals. In Column (1), the key indicator variable of interest captures the change in RMBS prices when the first transaction of the transaction pair occurred during the crisis and the second transaction occurred post-crisis. The estimates indicate that prices rebounded 6.7% during this period, as compared to price changes for the omitted indicator category, which were essentially zero. This result provides evidence of a meaningful reversal in prices (controlling for mortgage fundamentals) coming out of the financial crisis. A second indicator of interest captures the average change in prices for transaction pairs where the first transaction took place pre-crisis and the second transaction occurred during the crisis. The estimate on this indicator variable indicates a decrease in prices

of 10.4% (relative to the omitted category) heading into the crisis. As would be expected, increases in collateral default rates between transaction pairs are significantly correlated with price declines.

The remaining Columns in Table 5 test whether repeat transactions associated with negative operating cash flow insurance companies, considered "constrained" transactions, exhibit even larger price declines and rebounds, respectively. In Column (2) we estimate the price changes associated with an indicator variable equal to one if the second transaction in a transaction pair was associated with a negative operating cash flow insurance company. The estimates suggest a 5.06% greater price decline for repeat transactions where the second transaction was constrained, all else equal. Column (3) reports results when the second-transaction-is-constrained indicator is interacted with the pre-crisis/during-crisis indicator. The interaction estimates suggest that constrained transactions result in even greater declines when the transaction pairs span the beginning of the crisis.

We next construct an indicator variable to identify transaction pairs where the first transaction is associated with a negative operating cash flow company and the second transaction is not. This indicator allows for a comparison of the rebound in prices for the broad RMBS market as a whole against the rebounds off of constrained transactions. The estimates in Column (4) indicate that repeat transaction pairs, when the first transaction was a sell transaction of a negative operating cash flow firm, are associated with a price rebound of 20.3%. An interaction of the first-transaction-is-negative-cash-flow indicator with the during-crisis/post-crisis indicator suggests that price rebounds were concentrated among transactions that spanned the ending of the crisis. The result confirms that reversals were strongest when the first transaction in a transaction pair had the characteristics of a fire sale.

Overall, the results provided in Table 5 document an important piece of evidence in support of a fire sales hypothesis. The RMBS market as a whole exhibited price reversals, even after controlling for collateral quality. Our estimates indicate that broad RMBS market prices rebounded close to 10% off their crisis lows. The size of the estimation sample and magnitude of the estimates suggest these effects are more consistent with broad fire sales as opposed to one-off trades that produced price pressure in the RMBS market.

Price reversals, though consistent with a fire sale hypothesis, are also consistent with an alternative hypothesis. RMBS are priced based on a forecast. If market participants had especially poor forecasts during the peak of the crisis that subsequently turned out to be too pessimistic because the economic conditions were not as bad as expected, RMBS prices could demonstrate rebounds of the variety documented in Table 5. While such a reversal explanation is plausible, it does not explain the exaggerated decline and reversal pattern of the constrained sellers documented in Columns (2)-(5) of Table 5. This is especially true when considering the fact that the constrained sales were generated by negative operating cash flow insurance companies, an attribute of insurance companies that is likely to be uncorrelated with the market's expectations regarding RMBS fundamentals.

Section 4.2. Evidence of greater unexplained cross-sectional variation in prices

In this section, we evaluate the cross-sectional variance in RMBS prices during the financial crisis. Heightened cross-sectional variance in pricing is consistent with a lack of arbitrageurs helping to eliminate mispricings. This can occur when arbitrageurs themselves are constrained on account of leverage-induced liquidity constraints (Shleifer and Vishny (1997), Brunnermeier and Pedersen (2009)). In the case of fire sales, the lack of arbitrageurs, or more specifically, an unwinding of arbitrageurs' positions, can deepen the mispricing and exacerbate the impact of fire sales. One symptom of this type of episode is heightened cross-sectional variance in prices.

A careful analysis of cross-sectional variance in RMBS pricing must purge RMBS prices of the cross-sectional variance induced by variance in the collateral fundamentals. Thus, our analysis of variance in RMBS pricing focuses on the variance in pricing residuals. Controlling for changing collateral fundamentals is of particular importance during the financial crisis given the housing market collapse and subsequent spike in mortgage default rates. As in Section 4.1, we estimate a regression of RMBS prices on the set of mortgage fundamentals and harvest the residuals. Using a sample of residuals within each month of the regression, we calculate the standard deviation of residuals. Figure 4 plots the three-month moving average of the standard deviation of the residuals over the period 2006-2012. The plot documents little variance in the pricing residuals in the period preceding the crisis. Variance in the pricing residuals increases

three-fold during the crisis and tapers off coming out of the crisis. The plot reveals small surges in the variance of pricing during brief periods in 2011 and 2012, but the variance in residuals during these episodes do not match the heightened variance present during the crisis.

Section 4.3. Evidence of natural buyers leaving the market

Shleifer and Vishny (2011) argue that constraints facing industry specialists, those with the highest value for industry-specific assets, represent an essential feature of fire sales. Because industry specialists have the highest value for assets, constraints that limit the purchasing activity of industry specialists can result in assets being sold to entities outside the industry that cannot employ assets in their most efficient use, resulting in fire-sale prices. In financial markets, hedge funds specialized in fixed-income arbitrage would be industry specialists in the RMBS space. Mitchell and Pulvino (2011) provide evidence of hedge funds being forced to withdraw from markets in general. However, they do not have data of actual trades by hedge funds or changes in holdings of bonds. In this section, we investigate more narrowly whether natural buyers withdrew by focusing on insurance companies where we have holdings data.

Our RMBS transaction data contains the identity of the insurance companies involved in one side of a purchase or sell transaction. This feature of the data allows us to construct a sample that measures the volume of purchase transactions by individual insurance companies prior to, during, and after the crisis. One limitation of our analysis is the fact that the insurance companies in our sample obviously operate in the same industry, making an inter-industry test of the natural-buyer-leaving-the-market hypothesis impossible. We address this issue by exploiting cross-sectional variation in RMBS purchasing activity within the insurance firms in our sample. Using a sample of RMBS transactions between 2000 and 2005, we group each insurance company into quartiles based on their purchasing activity during the 2000 through 2005 time period. This approach relies on the argument that some insurance companies were more natural buyers of RMBS than others, by revealed preference. We then evaluate the purchasing patterns of top-quartile purchasers and bottom-quartile purchasers during the subsequent 2006 through 2012 time period. In this way our test can identify whether those insurance companies that demonstrated a proclivity for

purchasing RMBS between the years 2000-2005, our measure of "natural buyers" within the industry, subsequently reduced their purchasing of RMBS during the crisis at rates different than changes in the purchasing patterns of bottom-quartile purchasers.

Table 6 reports the results of a regression designed to explain variation in the purchasing activity of insurance companies through time. The dependent variable is measured as the natural log of the number of purchases in a given month, measured at the insurance company level. We construct a crisis indicator variable equal to one for each month in the sample that occurred during the crisis. We also construct a post-crisis indicator and a pre-crisis indicator. The pre-crisis indicator serves as the omitted group in the estimation. We include the log of total assets and log of the RBC ratio as insurance company controls. Column (1) reports results of a specification that includes the top purchaser indicator, the crisis and post-crisis indicators, and insurance company controls. The results indicate that the 2000-2005 top quartile purchasers were involved in 26.7% more purchase transactions over the subsequent 2006-2012 time period than purchasers in the second, third, and bottom quartiles. We create interaction terms designed to measure the purchasing activity of top quartile purchasers during the crisis and post-crisis. Estimates on these interaction terms are reported in Column (2) and indicate that top quartile purchasers were involved in 43.4% fewer transactions during the crisis in comparison to pre-crisis. The estimated coefficient on the interaction of the top quartile indicator with the post-crisis indicator suggests that top quartile purchasers were involved in 39.8% fewer transactions after the crisis than before the crisis. These estimates indicate that top quartile purchasers reduced their purchasing of RMBS more substantially during the financial crisis than their peers. The difference in the estimates on the two interaction terms in Column (2), a statistically significant difference of 3.6 percentage points, measures the rate at which top quartile purchasers re-entered the market after the crisis.[24] Evidence that indicates a re-entering of the market by the most natural buyers of RMBS is potentially consistent with the price reversal evidence documented in the previous section.

In Columns (3) and (4) of Table 6 we evaluate whether the pattern of leaving and re-entering the RMBS market for the top quartile RMBS purchasers is replicated by bottom quartile RMBS purchasers. Estimates in Column 3 indicate the bottom quartile purchasers were involved in 5.3% fewer purchase transactions

than purchasers in the second, third, and highest purchasing quintiles. This result essentially validates that insurance companies that purchased fewer RMBS in the years 2000-2005 continued to purchase fewer RMBS in the years 2006-2012. Column 4 reports estimates on the interaction of the bottom quartile purchaser indicator with crisis and post-crisis indicators. Estimates on the interaction terms indicate two interesting patterns. First, bottom quartile purchasers actually slightly increased their purchasing activity of RMBS during the crisis *relative* to higher quartile purchasers. Second, the difference in the estimated interaction terms is an insignificant 0.9 percentage point, indicating that bottom quartile purchasers never really left the RMBS market during the crisis relative to pre-crisis, and hence demonstrate no statistical pattern of returning to the RMBS market post-crisis.

Taken together, the results in Table 6 document empirical patterns that indicate that insurance companies that were the most active participants in the RMBS market prior to the crisis left the RMBS market at statistically significant rates during the crisis and returned to the RMBS market at statistically significant rates relative to their less-frequently purchasing peers. This pattern is not repeated by bottom quartile purchasers. In untabulated results we repeat the entire analysis using the dollar volume of purchasing activity as the dependent variable in the place of the number of transactions. The results are qualitatively and quantitatively similar. Variation in purchasing activity within the cross-section of natural purchasers through and out of the crisis appears consistent with the natural-buyer-leaving the market condition of fire sales set forth by Shleifer and Vishny (2011).

Section 5. Conclusion

The role of collateralized lending is a common theme in some recent influential papers on the financial crisis (Brunnermeier (2009), Shleifer and Vishny (2011)). These papers argue that the liquidation of financing positions which were collateralized by financial assets led to fire sales in financial markets. In this paper, we consider capital requirements as an important mechanism which may contribute to fire sales in financial markets, show that this mechanism was at work during the crisis for RMBS, and provide evidence of fire-sale activity in the RMBS market. We describe the economics of how capital requirements

can lead to fire sales and show that mark-to-market accounting is a critical requirement for such fire sales to occur. We propose and test hypotheses designed to identify a capital requirement channel at play in the transactions of non-agency RMBS by insurance companies. Understanding the economics surrounding the market valuation of non-agency RMBS during the financial crisis is important given the critical role that RMBS played in destabilizing financial institutions' balance sheets.[25]

We show that the interplay of mark-to-market accounting rules and credit-quality based capital requirements can create an economic incentive for a capital-constrained firm to sell credit-impaired financial assets even, potentially, at fire-sale prices. In particular, fair value accounting rules force financial firms to mark financial assets to market prices when they are impaired, thereby recognizing the loss associated with a decline in an asset's credit quality. Declines in credit quality have a second important effect, which is that they raise the capital costs associated with holding a credit-impaired asset on a balance sheet if the capital requirements are credit-quality sensitive. The capital costs associated with holding a credit-impaired asset may be more onerous than a firm is willing to bear. Seeking capital relief, capital-constrained firms may have to quickly sell credit-impaired assets, accepting liquidity discounts associated with an urgent sale.

We provide empirical evidence consistent with the capital requirement fire sale hypothesis. We find that insurance companies subject to mark-to-market statutory accounting practices with low risk-based capital ratios are more likely to sell RMBS, all else equal. When capital-constrained insurance companies do sell RMBS, they sell RMBS at prices lower than sales of non-capital constrained insurance companies. We further document that the fire-sale discounts of capital constrained firms increase as the credit quality of the asset being sold declines. This result is consistent with a regulatory system that assigns capital charges as a function of asset quality.

Our analysis employs data from insurance companies, specifically, although our results have broad implications for financial institutions of all types. Though calculated differently at banks than insurance companies, capital requirements can create similar incentives for banks to unload assets at fire-sale prices. While capital requirements for U.S. banks were not credit-quality sensitive for loans, they were for

structured finance securities such as RMBS, so that we would expect the issues raised in this paper to be relevant for RMBS transactions by banks as well. Many financial institutions and money managers allocate capital using value-at-risk (VaR). Such an allocation mechanism would also have similar implications for fire sales as assets that increase the most in their risk are the assets that will have the biggest impact on VaR and whose sales will be most advantageous in decreasing VaR. For such firms, reducing holdings of low risk assets would have little impact compared to selling the riskiest assets.

The various mechanisms that lead to fire sales were all at play in the RMBS market. There is no way to assess the relative importance of each mechanism with the data available. However, the data we have allows us to show that the market behaved very much like a market that was materially affected by fire sales.

References

Ambrose, Brent W., Kelly Nianyun Cai, and Jean Helwege, "Fallen Angels and Price Pressure." *Journal of Fixed Income*, 21 (2012), 74-86.

Babbel, David F. et al., "The Effect of Transaction Size on Off-the-Run Treasury Prices," *Journal of Financial and Quantitative Analysis*, 39 (2004), 595-611.

Badertscher, Brad, Jeffrey J. Banks, and Peter D. Easton, "A Convenient Scapegoat: Fair Value Accounting by Commercial Banks during the Financial Crisis," *The Accounting Review*, 87 (2012), 59-90.

Bank of England, "Financial Stability Report," 2008.

Becker, Bo, and Victoria Ivashina, "Reaching for Yield in the Bond Market," Working Paper, 2012.

Becker, Bo and Marcus Opp, "Replacing Ratings." Working Paper, 2013.

Benmelech, Efraim, and Nittai K. Bergman, "Liquidation Values and the Credibility of Financial Contract Renegotiation: Evidence from U.S. Airlines," *Quarterly Journal of Economics*, 123 (2009), 1635–77.

Bernanke, Ben S., "Rethinking Finance." Speech presented at the Sage Foundation and The Century Foundation Conference, New York, NY, 2012.

Boyson, Nicole M., Jean Helwege, and Jan Jindra, "Crises, Liquidity Shocks, and Fire Sales at Commercial Banks," Working Paper, 2012.

Boyson, Nicole M., Christof W. Stahel, and René M. Stulz, "Hedge Fund Contagion and Liquidity Shocks," *Journal of Finance*, 55 (2010), 1789-1816.

Brown, David B., Bruce I. Carlin, and Miguel Sousa Lobo, "Optimal Portfolio Liquidation with Distress Risk," *Management Science*, 56 (2010), 1997-2014.

Brunnermeier, Markus K., "Deciphering the liquidity and credit crunch 2007-2008," *Journal of Economic Perspectives*, 23 (2009), 77-100.

Brunnermeier, Markus K., and Lasse H. Pedersen, "Market Liquidity and Funding Liquidity," *Review of Financial Studies*, 22(2009), 2201–38.

Coval, Joshua D., and Erik Stafford, "Asset Fire Sales (and Purchases) in Equity Markets," *Journal of Financial Economics*, 86 (2007), 479–512.

Deng, Yongheng, John M. Quigley, and Robert Van Order, "Mortgage Terminations, Heterogeneity, and the Exercise of Mortgage Options," *Econometrica*, 68 (2000), 275-307.

Duffie, Darrell, "Presidential Address: Asset Price Dynamics with Slow-Moving Capital," *Journal of Finance*, 65 (2010), 1237-1267.

Ellul, Andrew, Pab Jotikasthira, and Christian T. Lundblad, "Regulatory Pressure and Fire Sales in the Corporate Bond Market," *Journal of Financial Economics*, forthcoming, 2010.

Ellul, Andrew et al., "Is Historical Cost Accounting a Panacea? Market Stress, Incentive Distortions, and Gains Trading," Working Paper, 2012.

Erel, Isil, Taylor Nadauld, and René M. Stulz, 2013. "Why Did U.S. Banks Invest in Highly-Rated Securitization Tranches?" *Review of Financial Studies*, forthcoming.

French, Kenneth R. et al., *The Squam Lake Report: Fixing the Financial System*, (Princeton University Press, 2010).

Gorton, Gary, and Andrew Metrick, "Securitized Banking and the Run on Repo," *Journal of Financial Economics*, 104 (2010), 425-451.

Heaton, John C., Deborah Lucas, and Robert L. McDonald, "Is Mark-to-Market Accounting Destabilizing? Analysis and Implications for Policy," *Journal of Monetary Economics*, 31 (2010), 64-75.

Herring, R., and Til Schuermann, "Capital Regulation for Position Risk in Banks, Securities Firms, and Insurance Companies," Scott, Hal S (Ed.), *Capital Adequacy Beyond Basel: Bank, Securities and Insurance*, (Oxford University Press, New York, chapter 1, 2005).

Koijen, R. A., and M. Yogo, "The Cost of Financial Frictions for Life Insurers," Working Paper, 2013.

Kraus, R. A., and H. Stoll, "Price Impacts of Block Trading on the New York Stock Exchange," *Journal of Finance* 27 (1972), 569-588.

Laux, Christian, "Financial Instruments, Financial Reporting, and Financial Stability," Working Paper, 2012.

Laux, Christian, and Christian Leuz, "Did Fair-Value Accounting Contribute to the Financial Crisis?" NBER Working Paper No. 15515, 2009.

Manconi, Alberto, Massimo Massa, and Yasuda Ayako, "The Role of Institutional Investors in Propagating the Crisis of 2007-2008," *Journal of Financial Economics*, 104 (2012), 491-518.

Mitchell, Mark, and Todd Pulvino, "Arbitrage Crashes and the Speed of Capital," *Journal of Financial Economics*, 104 (2011), 469-490.

Mitchell, Mark, Lasse Pedersen, and Todd Pulvino, "Slow Moving Capital," *American Economic Review*, 97 (2007), 215-220.

Pennington-Cross, Anthony, and Giang Ho, "The Termination of Subprime Hybrid and Fixed Rate Mortgages," Federal Reserve Bank of St. Louis Working Paper, 2006.

Plantin, Guillaume, Haresh Sapra, and Hyun Song Shin, "Marking-to-Market: Panacea or Pandora's Box?" *Journal of Accounting Research*, 46 (2008), 435-460.

Pulvino, Todd, "Do Fire-Sales Exist? An Empirical Study of Commercial Aircraft Transactions," *Journal of Finance*, 53 (1998), 939–78.

Shaffer, Sanders, "Fair Value Accounting: Villain or Innocent Victim – Exploring the Links between Fair Value Accounting, Bank Regulatory Capital and the Recent Financial Crisis," Federal Reserve Bank of Boston Quantitative Analysis Unit Working Paper, 2010.

Sherlund, Shane, "The Past, Present, and Future of Subprime Mortgages," Finance and Economics Discussion Series, Federal Reserve Board, 2008.

Shleifer, Andrei, "Do Demand Curves for Stocks Slope Down?" *Journal of Finance*, 1986, 579-590.

Shleifer, Andrei, and Robert W. Vishny, "Liquidation Values and Debt Capacity: A Market Equilibrium Approach," *Journal of Finance*, 47 (1992), 1343–66.

Shleifer, Andrei, and Robert W. Vishny, "The Limits of Arbitrage," *Journal of Finance*, 52 (1997), 35–55.

Shleifer, Andrei, and Robert Vishny, "Fire Sales in Finance and Macroeconomics," *Journal of Economic Perspectives*, 25 (2011), 29-48.

Notes

1. See, for instance, Bank of England (2008).

2. “The origins of the financial crisis: Crash course,” The Economist, September 7, 2013.

3. Erel, Nadauld, and Stulz (2013) detail the capital requirements that applied to banks at the time of the crisis and before. In the next section, we report the capital requirements that applied to insurance companies. Basle III, which is the revision of the risk-based capital requirements following the crisis, has a capital requirement for some of the riskiest assets that exceeds the value of the assets.

4. See Laux and Leuz (2009) for a review of the issues.

5. Trades in corporate bonds are reported to FINRA and the information is made publicly available through TRACE.

6. Banks did not have to report individual trades and the prices at which these trades were made (see Erel, Nadauld, and Stulz (2013)).

7. This will be the case when the debt contract is a combination of short-term and long-term debt, with the long-term debt creating a debt overhang.

8. An issue with selling the most liquid assets is that the financial institution’s portfolio of assets may become more concentrated and more illiquid. It follows that there are situations where it makes sense for a financial institution to sell illiquid assets even when it could sell liquid assets instead. See, for instance, Brown, Carlin, and Lobo (2010) for an analysis of some of these issues.

9. See Kraus and Stoll (1972) or Shleifer (1986) for examples of price pressure in equity markets or Babbel, Merrill, Meyer and deVilliers (2004) that study price pressure in Treasury bond secondary markets.

10. See Benmelech and Bergman (2009) for empirical evidence regarding the role of distress in fire sales of physical assets.

11. See Shleifer and Vishny (1998) for a theoretical model and Mitchell, Pedersen, and Pulvino (2007) and Mitchell and Pulvino (2010) for empirical evidence of this phenomenon.

12. We consider that fair value treatment applies when fair value losses are recognized through earnings. In general, if fair value treatment applies, it does so only for other than temporarily impaired securities.

13. NAIC Level 5 represents securities with CCC ratings. NAIC level 6 represents securities that are in or near default.

14. It is important to note that the typical securitization deal produces 17 unique bonds on average. Individual mortgages do not provide cash flows for individual bonds. Rather, the entire mortgage pool generates monthly principal and interest payments which provide interest payments to bond holders. Bond coupon payments are generated from the mortgage collateral pool according to pre-specified, prioritized cash flow rules.

15. We use MSA- and state-level indexes when ZIP-code indexes are unavailable.

16. Some of the extreme outliers appear to be obvious errors in the data, which is why we do not simply winzorize the outliers to values at the 99th and 1st percentiles.

17. This argument has been highlighted in conversations with three separate industry professionals.

18. The expected duration of senior RMBS in our sample is about 5 years, on average.

19. The impact of specific loan attributes on loan default rates is documented by Sherlund (2008), Deng, Quigley, and Van Order (2000), and Pennington-Cross and Ho (2006). Loans with high FICO scores, low loan-to-value ratios, and low debt-to-income ratios default less frequently.

20. Deal-level default rates are statistically significant in an estimation without calendar-time fixed effects.

21. Ten observations in our sample are trades in 2008 and 2009 that are associated with insurance companies that do not report capital levels for 2006. We use 2007 levels of capital for these observations.

22. One remaining bid-ask spread issue to consider is whether the first transaction in a repeat transaction pair was a purchase or sale transaction. Purchase-sale pairs would be expected to experience larger negative price changes than an otherwise comparable purchase-purchase pair because of bid-ask spreads. While this is a concern conceptually, we confirm in the data that price changes associated with purchase-sale paired transactions are not statistically different from price changes in purchase-purchase pairs.

23. In the discussion that follows, we refer to average price levels of securities that were originally rated AAA.

24. An F-test confirms the difference in the estimates is statistically significant at the 5% level.

25. See Erel, Nadauld, and Stulz (2013) for a discussion of the importance of RMBS and other structured finance instruments on the balance sheet of financial institutions.

Figure 1. A Numerical Example of Capital Requirements in the Insurance Industry.

	Before MBS Downgrade			After MBS Downgrade			After Hypothetical CCC-Rated MBS Fire Sale		
	Statement Value	RBC net Factor	Risk-Based Capital	Statement Value	RBC net Factor	Risk-Based Capital	Statement Value	RBC net Factor	Risk-Based Capital
Asset Risk									
NAIC Class 1 Bonds (AAA, AA, A)	100,000,000	0.004	400,000	99,000,000	0.004	396,000	99,500,000	0.004	398,000
NAIC Class 2 Bonds (BBB)	20,000,000	0.013	260,000	20,000,000	0.013	260,000	20,000,000	0.013	260,000
NAIC Class 5 Bonds (CCC)				600,000	0.23	138,000	0	0.23	0
Bonds subject to size factor			660,000			794,000			658,000
Size Factor			1.7			1.7			1.7
Total RBC for Bonds			1,122,000			1,349,800			1,118,600
Investments in Common Stock	1,000,000	0.2925	292,500	1,000,000	0.2925	292,500	1,000,000	0.2925	292,500
Asset Concentration Factor			45,000			45,000			45,000
Total Asset Risk - C1			1,459,500			1,687,300			1,456,100
Total Insurance Risk - C2			874,250			874,250			874,250
Total Interest Risk - C3			672,750			672,750			672,750
Total Business Risk - C4			160,160			160,160			160,160
Total Risk Based Capital			3,166,660			3,394,460			3,163,260
Effect of Covariance			-701,982			-701,982			-701,982
Company Action Level RBC			2,464,678			2,692,478			2,461,278
Surplus (a.k.a. Capital)			5,500,000			5,100,000			5,000,000
Asset Valuation Reserve			75,000			75,000			75,000
Dividend Liability			25,000			25,000			25,000
Total Adjusted Capital			5,600,000			5,200,000			5,100,000
RBC Ratio			2.272			1.931			2.072

Figure 2. Monthly Average RMBS Transaction Prices, January 2000 - January 2012

This figure plots the average price paid in RMBS transactions of insurance companies over the sample period. Individual prices from 14,300 unique transactions are averaged within a given month.

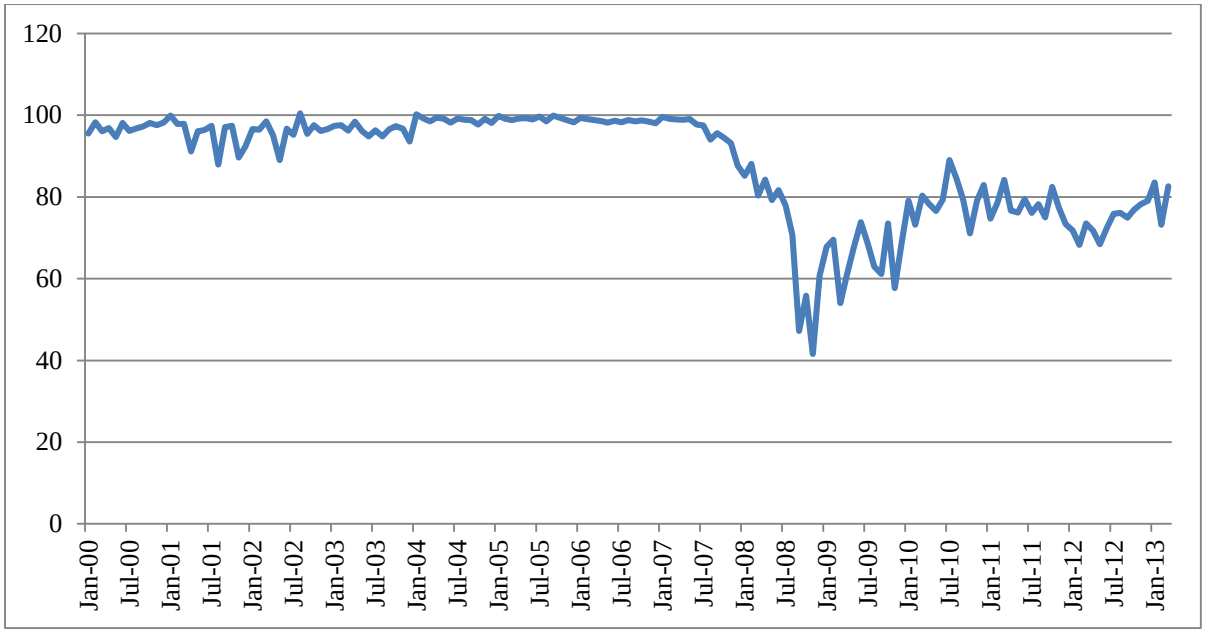

Figure 3. Average RMBS Pricing Residuals

This figure plots the residuals from a regression designed to explain variation in RMBS transaction prices. The dependent variable in the pricing regression is the level of RMBS transaction prices. The control variables include one-month lagged default rates, cumulative rates of house price appreciation, mortgage interest rates, FICO scores, LTV ratio, and the fraction of mortgages that have adjustable-rate features, are owner-occupied, provide full income documentation, and are refinances. We also control for the change in the 5-year t-bond rate from the time of deal origination. The estimation sample period is January 2006-December 2012.

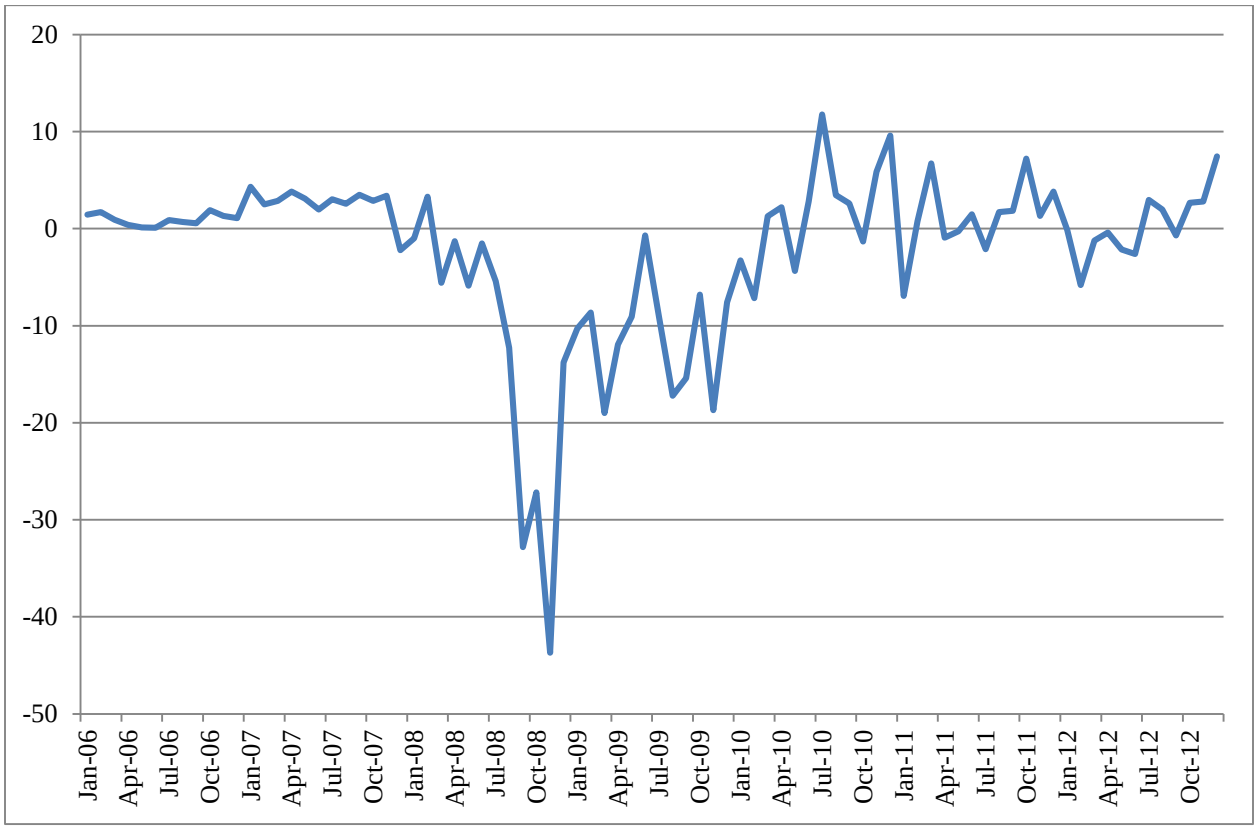

Figure 4. Three-month Moving Average of the Standard Deviation in RMBS Pricing Residuals

This figure plots the three-month moving average of the standard deviation in residuals from a regression designed to explain variation in RMBS transaction prices. The dependent variable in the pricing regression is the level of RMBS transaction prices. The control variables include one-month lagged default rates, cumulative rates of house price appreciation, mortgage interest rates, FICO scores, LTV ratio, and the fraction of mortgages that have adjustable-rate features, are owner-occupied, provide full income documentation, and are refinances. We also control for the change in the 5-year t-bond rate from the time of deal origination. The estimation sample period is January 2006-December 2012.

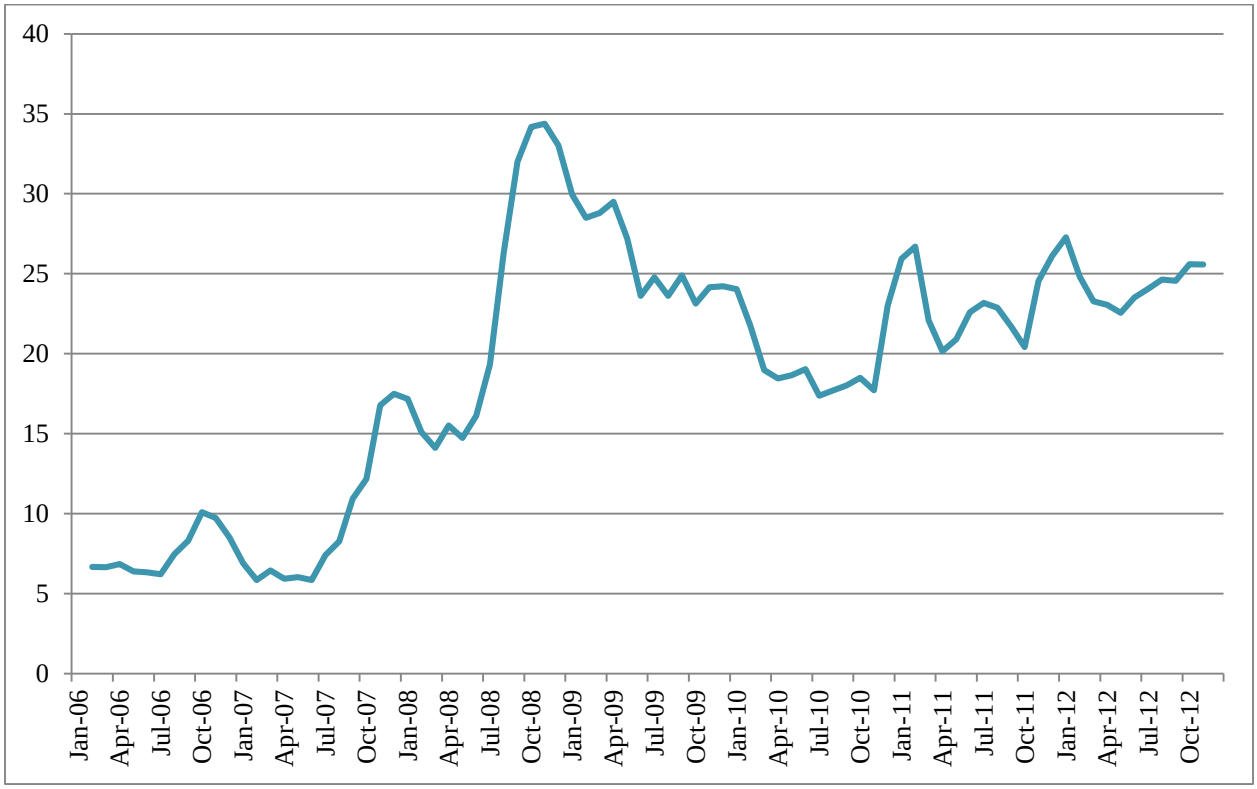

Table 1. Summary Statistics.

The RMBS transaction sample includes RMBS's held on the balance sheet of life and P&C insurance companies. The sample includes bonds with at least two transactions, where the second transaction occurred during the years January 2006 through December 2012. The variable "average change in bond price" calculates the change in transaction price *on the same RMBS* from the first transaction to the second. The data classify each transaction as a "purchase" or a "sale." We report attributes of the mortgage collateral supporting the RMBS at the time of the second transaction.

		Level of Bond Price Transactions			Average Change in Bond Price from First Transaction to Second Transaction			% of Transactions that are Sales	Average Mortgage Collateral Default Rate in Month Prior to Observed Transaction
Year, Qtr	N	Average	Median	Std. Dev.	Average	Median	Std. Dev.		
2006 Q1	626	99.36	100.00	3.68	-0.17%	0.00%	3.49%	60.06%	3.83%
2006 Q2	688	98.95	100.00	3.24	0.00%	0.00%	10.07%	66.42%	3.97%
2006 Q3	681	98.89	100.00	5.05	3.19%	0.00%	26.32%	65.64%	4.90%
2006 Q4	647	96.71	100.00	12.33	-2.51%	0.00%	12.40%	66.92%	5.83%
2007 Q1	655	99.24	100.00	4.37	-0.46%	0.00%	4.33%	67.48%	5.76%
2007 Q2	532	98.17	99.83	5.54	-1.33%	-0.14%	5.24%	61.84%	6.72%
2007 Q3	524	96.58	98.97	7.42	-3.03%	-0.78%	7.44%	38.36%	7.66%
2007 Q4	676	93.38	99.27	16.54	-3.89%	-0.31%	14.15%	63.02%	7.72%
2008 Q1	328	84.20	92.06	18.15	-14.31%	-6.59%	18.60%	11.59%	9.50%
2008 Q2	262	82.75	90.92	20.27	-13.91%	-6.78%	20.13%	24.81%	11.32%
2008 Q3	188	76.22	79.86	21.32	-17.71%	-12.56%	25.76%	16.49%	10.82%
2008 Q4	235	67.05	73.64	29.80	-27.42%	-17.80%	32.55%	25.53%	13.61%
2009 Q1	310	73.35	84.75	28.00	-13.78%	-5.50%	43.82%	54.84%	13.10%
2009 Q2	276	73.19	86.38	29.03	-16.68%	-0.91%	32.44%	64.49%	17.36%
2009 Q3	310	66.51	71.18	27.19	-20.66%	-12.31%	33.96%	61.61%	17.98%
2009 Q4	298	69.25	73.47	28.82	-16.16%	-9.45%	37.52%	55.37%	18.20%
2010 Q1	208	75.65	83.44	25.67	-6.93%	-0.61%	38.09%	46.15%	18.59%
2010 Q2	219	79.19	86.50	21.35	-3.14%	-0.90%	33.30%	47.03%	21.98%
2010 Q3	506	84.82	92.36	19.16	-0.66%	0.16%	28.12%	38.34%	21.40%
2010 Q4	251	81.56	86.85	20.70	-1.06%	0.00%	32.56%	54.58%	22.89%
2011 Q1	484	76.87	88.00	26.09	-9.44%	-0.97%	45.43%	68.80%	25.84%
2011 Q2	479	78.15	85.82	23.96	-3.26%	-0.81%	45.10%	56.78%	23.92%
2011 Q3	460	74.05	82.39	26.26	-11.74%	-2.52%	32.08%	52.17%	25.95%
2011 Q4	1240	72.57	79.98	29.51	2.22%	-1.66%	151.06%	80.97%	26.99%
2012 Q1	593	65.02	67.50	27.96	-2.07%	-0.04%	58.50%	62.06%	30.35%
2012 Q2	509	68.29	72.56	27.89	5.47%	-0.33%	104.01%	57.56%	27.80%
2012 Q3	573	72.36	78.95	27.48	8.96%	1.29%	78.48%	60.91%	28.45%
2012 Q4	1542	76.06	85.33	27.31	25.40%	1.38%	236.41%	74.38%	28.94%

Table 2. Hazard Model: Likelihood of Selling RMBS.

This table presents the results of a Cox proportional hazard model which estimates the likelihood of selling an RMBS following an observed purchase. We track the monthly, real-time collateral attributes of any given RMBS following an observed purchase between 2006-2008. The model estimates a baseline hazard through time, where a sale represents failure. Above and below-median capital firms are sorted based on an annual calculation of the median risk-based capital ratio (RBC) for P&C and life firms, respectively. Each of the measures of collateral quality measure real-time attributes of the mortgage collateral generating the RMBS cash flows. We cluster standard errors by month and report estimated coefficients as opposed to estimated hazard ratios.

	Cox Proportional Hazard Model: Propensity to Sell RMBS Following Observed Purchase Sample: 2006 - 2008 Note: Coefficients Reported (Not Hazard Ratios)				
	P&C and Life Sample (1)	P&C Sample (2)	P&C Sample (3)	Life Sample (4)	Life Sample (5)
Property & Casualty Indicator	0.423**				
	(2.529)				
Below-Median Risk-Based Capital Ratio		0.482**	0.546*	0.033	-0.058
		(2.340)	(1.807)	(0.136)	(-0.189)
Below-Median Risk-Based Capital Ratio* Default Rate t-1			-1.066		1.364
			(-0.453)		(0.784)
Deal-Level Measures of Collateral Quality:					
Default Rate month t-1	0.914	-0.708	-0.090	1.666*	1.080
	(1.124)	(-0.309)	(-0.0343)	(1.871)	(0.830)
Cumulative House Price Appreciation	-0.007*	-0.022***	-0.022***	-0.003	-0.003
	(-1.700)	(-2.685)	(-2.661)	(-0.630)	(-0.601)
Mortgage Rate	-0.004	0.045	0.045	-0.015	-0.017
	(-0.0960)	(0.520)	(0.519)	(-0.353)	(-0.387)
FICO Score	0.004**	0.004	0.004	0.004**	0.004**
	(2.198)	(1.491)	(1.493)	(1.970)	(2.038)
Combined Loan-to-Value Ratio	0.009	0.005	0.005	0.011	0.011
	(0.856)	(0.258)	(0.276)	(0.944)	(0.952)
Percentage of A.R.M.'s	0.424**	0.528	0.529	0.339*	0.336*
	(2.290)	(1.482)	(1.486)	(1.924)	(1.929)
Percent of Loans Owner Occupied	1.086***	1.122	1.112	1.006***	1.017***
	(2.620)	(1.516)	(1.523)	(2.601)	(2.668)
Percent of Loans No Doc./Low Doc.	0.232	-0.432	-0.429	0.410	0.403
	(0.832)	(-1.096)	(-1.086)	(1.209)	(1.196)
Percent of Refinance Loans	-0.167	0.355	0.372	-0.366	-0.364
	(-0.545)	(0.562)	(0.590)	(-1.090)	(-1.082)
Calendar Quarter Fixed Effects	Yes	Yes	Yes	Yes	Yes
Cluster Standard Errors by Month	Yes	Yes	Yes	Yes	Yes
Number of Subjects:	8867	1996	1996	6721	6721
Number of Failures (Sales):	1185	311	311	849	849
Total Number of Obs.	211610	41159	41159	167094	167094
Log likelihood	-9545.4	-1995.3	-1995.0	-6616.1	-6616.0
Prob > x2	0.000	0.000	0.000	0.000	0.000

Table 3. Are the Sales of Constrained Firms Associated with Pricing Discounts?

The dependent variable in this OLS estimation is the change in price on a given RMBS between two transactions, where the second transaction occurred between Q3 2007 and Q3 2009. We classify insurance companies as having experienced an adverse shock to their capital if the insurance company has experienced negative operating cash flow in the year of the transaction. Operating cash flow does not include gains or losses on account of a change in the market value of the non-agency RMBS held on an insurance company's balance sheet. We measure RMBS fundamentals using the change in the collateral attributes from the prior transaction to the current transaction. Mortgage attributes include one-month lagged default rates, cumulative rates of house price appreciation, mortgage interest rates, FICO scores, LTV ratio, and the fraction of mortgages that have adjustable-rate features, are owner-occupied, provide full income documentation, are refinances. We create an indicator variable for sell transactions. The model includes quarter fixed-effects, and the interaction of quarter fixed effects with a variable that measures the number of months from the prior transaction. We cluster standard errors by month of the second transaction and by firm.

	Dependent Variable: % Change in Price from Prior Transaction					
	P & C Insurers: Q3 2007 - Q3 2009		Life Insurers: Q3 2007 - Q4 2008		Life Insurers: Q1 2009 - Q3 2009	
	Neg. Op. Cash Flow	Pos. Op. Cash Flow	Neg. Op. Cash Flow	Pos. Op. Cash Flow	Neg. Op. Cash Flow	Pos. Op. Cash Flow
	(1)	(2)	(3)	(4)	(5)	(6)
Operating Cash/2006 Capital * Sale Indicator	0.387*	-0.013	0.015	-0.010	0.215***	0.028
	(1.90)	(0.11)	(0.20)	(0.32)	(3.96)	(0.80)
Operating Cash/2006 Capital	-0.371*	0.013	0.022	0.018	-0.091***	-0.062**
	(1.85)	(0.17)	(0.62)	(1.50)	(4.14)	(2.53)
Sale Indicator	0.038	-0.044	0.003	-0.028	0.057	-0.222***
	(0.56)	(1.03)	(0.06)	(0.37)	(0.69)	(3.00)
Change in Collateral Quality from Prior Trade:						
Chg. Default Rate month t-1	-1.157*	-0.222	-1.105**	-0.885**	0.010	-0.617
	(1.70)	(1.15)	(2.04)	(2.44)	(0.04)	(1.23)
Chg. Cumulative House Price Appreciation	-0.007	-0.002	0.006*	0.002	0.005	-0.010**
	(1.08)	(0.84)	(1.71)	(1.14)	(0.84)	(2.18)
Chg. Mortgage Rate	0.122**	0.089***	0.108**	0.028**	0.059***	0.039**
	(2.10)	(3.98)	(2.14)	(2.46)	(5.44)	(2.44)
Chg. FICO Score	0.006	0.012*	0.012**	0.001*	0.012*	-0.011
	(0.35)	(1.95)	(2.03)	(1.68)	(1.94)	(1.21)
Chg. Combined Loan-to-Value Ratio	0.011	-0.004	0.014	0.003	-0.044*	-0.016
	(0.35)	(0.25)	(0.38)	(0.15)	(1.73)	(0.75)
Chg. Percentage of A.R.M.'s	5.663***	1.096**	0.625*	-0.086	0.347	-1.037
	(3.57)	(2.54)	(1.95)	(0.53)	(0.60)	(1.04)
Chg. Percent of Loans Owner Occupied	1.249	0.881	-0.206	0.107	-0.692	0.801
	(1.06)	(0.93)	(0.26)	(0.12)	(0.42)	(0.20)
Chg. Percent of Loans No Doc./Low Doc.	-1.274	-0.394	0.669	-0.040	1.752***	1.851
	(1.34)	(0.62)	(1.25)	(0.04)	(4.14)	(0.56)
Chg. Percent of Refinance Loans	0.174	1.020	1.171	-0.477	-1.660*	0.353
	(0.07)	(1.37)	(1.17)	(0.86)	(1.76)	(0.13)
Chg. Geographic Concentration	-0.070	-0.160	-0.008	-0.138**	0.095	-0.007
	(0.55)	(1.62)	(0.06)	(2.04)	(0.77)	(0.07)
Months from Prior Trade	0.008*	-0.005	0.000	-0.001	-0.003	-0.009**
	(1.79)	(1.55)	(0.02)	(0.56)	(1.12)	(2.24)
Chg. in 5-year T-Bond Rate	0.088	0.065***	0.006	0.030	0.091**	0.105**
	(1.63)	(2.59)	(0.13)	(1.57)	(2.41)	(2.30)
Constant	0.075	0.038	0.040*	-0.045	-0.101	-0.019
	(1.06)	(0.74)	(1.71)	(0.94)	(1.46)	(0.21)
Quarter Fixed Effects	yes	yes	yes	yes	yes	yes
Quarter Fixed Effects * Months from Prior Trade	yes	yes	yes	yes	yes	yes
Cluster Standard Errors by Firm	yes	yes	yes	yes	yes	yes
Cluster Standard Errors by Month	yes	yes	yes	yes	yes	yes
Observations	210	846	378	1045	214	140
Adj. R2	0.412	0.398	0.572	0.300	0.719	0.435

Table 4. Are the Pricing Discounts on Sales of Constrained Firms Larger for RMBS of Lower Credit Quality?

The dependent variable in this OLS estimation is the change in price on a given RMBS between two transactions, where the second transaction occurred between Q3 2007 and Q3 2009. The sample in this table includes changes in prices where the second transaction was either a purchase or a sale. We create a separate indicator variable for sell transactions. We classify insurance companies as having experienced an adverse shock to their capital if the insurance company has experienced negative operating cash flow in the year of the second transaction. We calculate collateral default rates as being above or below-median based on the collateral default rate at the time of the second transaction. We measure RMBS fundamentals using the change in the collateral attributes from the prior transaction to the current transaction. The model includes quarter fixed-effects, and the interaction of quarter fixed effects with a variable which measures the number of months from the prior transaction. We cluster standard errors by the month of the second transaction and by firm.

	Dependent Variable: % Change in Price from Prior Transaction		
	P & C Insurers: Q3 2007 - Q3 2009 Neg. Op. Cash Flow	Life Insurers: Q3 2007 - Q4 2008 Neg. Op. Cash Flow	Life Insurers: Q1 2009 - Q3 2009 Neg. Op. Cash Flow
	(1)	(2)	(3)
Operating Cash/2006 Capital * Sales * Above-Median Defaults	0.645*	0.071	0.333***
	(1.82)	(0.58)	(5.22)
Operating Cash/2006 Capital * Above-Median Defaults	-0.730*	-0.000	-0.132**
	(1.93)	(0.00)	(2.10)
Operating Cash/2006 Capital * Sale Indicator	0.041	-0.011	-0.031
	(0.16)	(0.18)	(0.47)
Sale Indicator * Above-Median Defaults	-0.011	-0.081	0.184**
	(0.07)	(1.20)	(2.31)
Operating Cash/2006 Capital	0.032	0.028	0.019
	(0.16)	(0.41)	(0.26)
Sale Indicator	0.014	0.041	-0.067
	(0.13)	(1.19)	(0.63)
Above-Median Defaults	-0.040	0.001	0.045
	(0.45)	(0.03)	(0.47)
Change in Collateral Quality from Prior Trade:			
Chg. Cumulative House Price Appreciation	-0.004	0.006	0.006
	(0.88)	(1.29)	(1.43)
Chg. Mortgage Rate	0.141**	0.084*	0.068**
	(2.42)	(1.92)	(2.53)
Chg. FICO Score	0.007	0.014***	0.016**
	(0.47)	(11.55)	(2.04)
Chg. Combined Loan-to-Value Ratio	-0.016	0.006	-0.028
	(0.30)	(0.20)	(1.42)
Chg. Percentage of A.R.M.'s	5.929***	0.853**	0.426
	(3.40)	(2.22)	(0.76)
Chg. Percent of Loans Owner Occupied	0.944	-0.217	-0.265
	(0.92)	(0.25)	(0.17)
Chg. Percent of Loans No Doc./Low Doc.	0.259	1.571**	1.407***
	(0.19)	(2.20)	(4.23)
Chg. Percent of Refinance Loans	-1.805	1.399*	-1.498**
	(0.80)	(1.65)	(2.03)
Chg. Geographic Concentration	-0.052	0.032	0.123***
	(0.48)	(0.22)	(3.72)
Months from Prior Trade	0.006	-0.002	-0.004
	(1.48)	(0.61)	(1.31)
Chg. in 5-year T-Bond Rate	0.086**	-0.001	0.080***
	(2.39)	(0.01)	(2.74)
Constant	0.075*	0.030	-0.117
	(1.89)	(0.88)	(1.15)
Quarter Fixed Effects	yes	yes	yes
Quarter Fixed Effects * Months from Prior Trade	yes	yes	yes
Cluster Standard Errors by Firm	yes	yes	yes
Cluster Standard Errors by Month	yes	yes	yes
Observations	210	378	214
Adj. R2	0.416	0.554	0.739

Table 5. Evidence of RMBS Price Reversals.

The dependent variable in this OLS estimation is the change in price on a given RMBS between two transactions, where the second transaction occurred in the years 2006 – 2012 and the first transaction occurred anytime between 2000 and 2012. We construct six unique indicator variables that are equal to one for transaction pairs that span time periods of interest. Two indicator variables are of interest. The first captures transaction pairs where the first transaction occurred pre-crisis (pre-Q3 2007) and the second transaction occurred during the crisis (Q3 2007 – Q3 2009). The second transaction pair of interest occurs where the first transaction occurred during the crisis (Q3 2007-Q3 2009) and the second occurred post-crisis (after Q3 2009). We construct an indicator variable that captures whether the first or second transaction was a constrained transaction – one that involved an insurance company that had experienced negative operating cash flows in the year of the transaction. The variable *second transaction is neg. operating cash transaction* identifies transaction pairs where the second transaction was associated with an insurance company that experienced negative operating cash flows in the year of the second transaction. The variable *first transaction is neg. operating cash transaction* identifies transaction pairs where the first transaction was associated with an insurance company that experienced negative operating cash flows in the year of the first transaction. The variable names in the table describe the remaining time periods captured by each of the time-span indicator variables. We include the standard set of collateral control variables as in previous tables and as described in the text, with the exception of *cumulative house price appreciation, mortgage rate, months from prior trade,* and *change in 5-year T-bond rate*, each of which are highly collinear with the time span indicators that are designed to capture time periods of interest. Standard errors are clustered by both bond and month of transaction.

	Dependent Variable: % Change in Price from Prior Transaction				
	(1)	(2)	(3)	(4)	(5)
Time Frame of Repeat Transaction Pairs:					
Indicator: First Pre-Crisis, Second During Crisis * Second Transaction is Neg Operating Cash Transaction			-13.498**		
			(2.11)		
Second Transaction is Neg. Operating Cash Transaction		-5.058**	0.043		
		(2.29)	(0.02)		
Indicator: First During Crisis, Second Post Crisis * First Transaction is Neg Operating Cash Transaction					18.397***
					(3.44)
First Transaction is Neg. Operating Cash Transaction				20.346***	8.784***
				(5.57)	(4.30)
Indicator: First During Crisis, Second Post Crisis	6.736***	6.639***	6.620***	4.060*	3.214
	(3.33)	(3.29)	(3.29)	(1.79)	(1.35)
Indicator: First Pre-Crisis, Second During Crisis	-10.432***	-10.154***	-9.618***	-10.752***	-10.758***
	(3.78)	(3.73)	(3.73)	(3.85)	(3.84)
Indicator: First Transaction During Crisis, Second Transaction During Crisis	-5.735***	-5.150***	-5.754***	-6.928***	-6.310***
	(4.96)	(4.23)	(5.10)	(5.87)	(5.18)
Indicator: First Transaction Post-Crisis, Second Transaction Post-Crisis	2.434***	2.420***	2.440***	2.447***	2.437***
	(2.83)	(2.82)	(2.84)	(2.84)	(2.83)
Indicator: First Transaction Pre-Crisis, Second Transaction Post-Crisis	-7.506***	-7.646***	-7.688***	-8.428***	-8.631***
	(3.00)	(3.06)	(3.08)	(3.41)	(3.49)
Indicator: First Transaction Pre-Crisis, Second Transaction Pre-Crisis (Omitted Category)					
Change in Collateral Quality from Prior Trade:					
Chg. Default Rate month t-1	-99.083***	-98.404***	-98.057***	-94.645***	-93.722***
	(15.37)	(15.50)	(15.54)	(14.47)	(14.25)
Chg. FICO Score	0.086	0.085	0.086	0.074	0.069
	(0.87)	(0.86)	(0.87)	(0.75)	(0.70)
Chg. Combined Loan-to-Value Ratio	0.475	0.467	0.465	0.445	0.441
	(1.40)	(1.38)	(1.38)	(1.34)	(1.34)
Chg. Percentage of A.R.M.'s	28.088	28.532	29.177	30.191	31.241
	(1.31)	(1.33)	(1.36)	(1.43)	(1.48)
Chg. Percent of Loans Owner Occupied	34.604	33.652	32.160	29.673	28.612
	(1.63)	(1.58)	(1.51)	(1.46)	(1.43)
Chg. Percent of Loans No Doc./Low Doc.	-14.966	-14.833	-15.250	-12.073	-11.152
	(1.03)	(1.03)	(1.07)	(0.84)	(0.77)
Chg. Percent of Refinance Loans	34.896	34.809	34.808	37.479	38.685
	(1.42)	(1.42)	(1.42)	(1.55)	(1.59)
Chg. Geographic Concentration	-53.787***	-53.598***	-53.773***	-50.002***	-49.239***
	(2.91)	(2.90)	(2.93)	(2.83)	(2.83)
Constant	1.232***	1.236***	1.212***	1.144***	1.137***
	(3.72)	(3.74)	(3.67)	(3.46)	(3.44)
Cluster Standard Errors by Bond	yes	yes	yes	yes	yes
Cluster Standard Errors by Month	yes	yes	yes	yes	yes
Observations	14172	14172	14172	14172	14172
Adj. R2	0.172	0.173	0.174	0.181	0.182

Table 6. Purchasing Patterns of "Natural Buyers" During and After of the Financial Crisis.

This table reports the results of an OLS regression designed to explain variation in RMBS purchasing activity. The dependent variable is measured as the natural log of the number of RMBS purchases in a given month, measured at the insurance company level. We sort each insurance company in our sample into quartiles based on their RMBS purchasing activity over the period 2000-2005. We then estimate regressions of purchasing activity over the subsequent 2006-2012 sample period. We create a crisis period (Q3 2007 – Q3 2009) indicator variable and a post-crisis (post-Q3 2009) period indicator equal to one for trades that occurred during the respective periods. We control for insurance company attributes such as the log of the RBC ratio and log of total assets. Standard errors are clustered at the company level and by quarter of transaction.

	Dependent Variable: Log # of Purchases in Month (Measured at Insurance Company Level)			
	(1)	(2)	(3)	(4)
Top Quartile Purchaser Indicator * Crisis Indicator		-0.434***		
		(7.17)		
Top Quartile Purchaser Indicator * Post-Crisis Indicator		-0.398***		
		(7.72)		
Bottom Quartile Purchaser Indicator * Crisis Indicator				0.163***
				(5.01)
Bottom Quartile Purchaser Indicator * Post-Crisis Indicator				0.154***
				(5.02)
Top Quartile Purchaser Indicator	0.267***	0.589***		
	(6.57)	(12.03)		
Bottom Quartile Purchaser Indicator			-0.053***	-0.177***
			(2.96)	(6.36)
Crisis Indicator	-0.172***	-0.059***	-0.173***	-0.211***
	(6.88)	(4.59)	(6.93)	(6.86)
Post-Crisis Indicator	-0.160***	-0.056***	-0.161***	-0.197***
	(7.20)	(4.02)	(7.33)	(7.38)
Log Regulatory-Based Capital Ratio	0.001	0.001	0.004	0.004
	(0.25)	(0.20)	(0.71)	(0.71)
Lot Total Assets	0.059***	0.059***	0.074***	0.074***
	(8.27)	(8.28)	(8.36)	(8.37)
Constant	-1.312***	-1.396***	-1.630***	-1.600***
	(6.85)	(7.44)	(7.15)	(6.97)
Standard Errors Clustered at Company Level	yes	yes	yes	yes
Standard Errors Clustered by Quarter	yes	yes	yes	yes
Observations	28544	28544	28544	28544
Adj. R2	0.155	0.173	0.118	0.121

Appendix. An Illustration of Capital Requirements and Forced Sales

We focus on capital requirements for insurance companies in this paper. A detailed numerical example can help to illustrate the capital requirements and accounting mechanism at play.

In Figure 1 we provide key aspects of a hypothetical risk-based capital (RBC) calculation for an insurance company. There are four categories of risks that are explicitly considered in an RBC calculation. We focus specifically on asset risk in this study. Each asset held by the company is categorized into six NAIC classes that correspond to various financial strength ratings. The asset value is scaled by a risk weighting, called a RBC Net Factor, to calculate risk-based capital as part of the company action level RBC calculation. Lower asset quality is associated with a higher RBC Net Factor and, thus, higher risk-based capital. Higher risk-based capital leads to a higher company action level RBC and a corresponding increase in capital that must be held. In our example, we consider an insurance company that is close to the mandatory company action level capital threshold with an RBC ratio just above two. A portion of the bond portfolio is downgraded from AAA to CCC, throwing the firm below the required RBC ratio where the regulator would be required to assume control of the firm. The example concludes with a demonstration of how selling the CCC-rated assets, even at fire sales prices, can restore the firm to acceptable capital levels.

The details of the example are as follows. The first step in the RBC ratio calculation is to multiply the face value of a bond by the "RBC net factor," where the risk adjustment factor is a function of the bond's credit rating. Bonds rated AAA, AA, and A are charged a net factor of 0.004. Bonds rated BBB are assigned a net factor of 0.013, BB-rated bonds are charged 0.046, B-rated bonds 0.10, CCC-rated bonds 0.23, and bonds at or near default are assigned a net factor of 0.30. Note that for the riskiest securities, the capital requirement is 75 times the capital requirement for the safest securities. Aside from credit risk-based factors, bonds are also subject to a "size factor," which we hold constant at 1.7 across all bonds in this example.

The relation between RBC net factors and credit quality lies at the heart of a capital requirements-OTTI-fire sale hypothesis. As detailed in Figure 1, we consider a hypothetical portfolio with $100M in bonds rated AAA, AA, or A, and $20M in bonds rated BBB. The total risk-based capital for the bonds held

by the firm is $1,122M, calculated as (($100M*0.004) + ($20M*0.013)) *1.7. Other risk factors (total asset risk, insurance risk, interest risk, and business risk) and a covariance adjustment are then added in to arrive at a company action level risk-based capital number of $2.46M. Company action level risk-based capital is then scaled by capital. In our example, capital is equal to $5.6M. Thus, the initial regulatory RBC ratio is equal to 2.27 ($5.60M/$2.46M), above the regulatory threshold of 2.

Holding every other aspect of the RBC ratio calculation constant, we next consider the effect of a downgrade of $1M worth of AAA-rated bonds to a CCC-rating, and assume that the market for CCC-rated bonds is at 60 cents on the dollar. The downgrade and OTTI accounting create two important effects. First, the insurance company must mark the face value of the bond from $1M to $600K. Second, it must recognize the $400K loss in its earnings which has the effect of reducing capital from the initial amount of $5.60M to $5.20M. The RBC net factor on a CCC-rated bond is equal to 0.23, making the risk-based capital on the downgraded bond equal to $138K ($600K*0.23). Holding everything else constant, the increased risk charge results in a company action level RBC amount of $2.69M, a $227K increase from the original company action level RBC of $2.46M. The higher risk-based capital amount, in tandem with a lower level of capital on account of the forced recognition of the loss (OTTI accounting), renders a new RBC ratio of 1.93, below the regulatory threshold of 2.

Consider the following possible response from the firm. Selling the $600K of CCC-rated bonds at a fire-sale price of $500K would allow the firm to reinvest $500K into AAA-rated securities. Doing so would force the firm to recognize the additional loss of $100K, leaving capital at $5.10M. Applying the lower RBC net factor to the new level of $99.5M in AAA securities, holding everything else constant, results in a company action level RBC amount of $2.46M. When compared against the capital amount of $5.10M, the resultant regulatory capital ratio is restored to 2.07, just above the regulatory threshold.

The preceding numerical example was constructed as a stylized example designed to illustrate the interaction of risk-based capital calculations and asset quality. The key insights from the example are (1) OTTI accounting forces the recognition of losses when security values decline, and (2) capital charges increase sharply as asset quality falls below investment grade.