Were there fire sales in the RMBS market?

by

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Abstract

Prices of non-agency residential mortgage-backed securities (RMBS) declined dramatically 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 surprising as, given the need to sell assets, these institutions presumably could have sold more liquid assets. In this paper, we provide an explanation for why financial institutions may have engaged in fire sales 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 create incentives for 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. Further, we find that, in general, RMBS prices behaved as would be expected in the presence of fire sales.

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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 and after the crisis were designed to decrease the risk of fire sales (French et al. (2009) and Bernanke (2012)). Of particular concern were potential fire sales of private label residential mortgage-backed securities (RMBS).[1] These securities, collateralized by subprime and Alt-A loans, were held in large quantities by financial institutions so that sharp decreases in their value could weaken such institutions, and make the crisis worse.[2] Indeed, an analysis of transaction-level data reveals striking declines in the value of RMBS through the crisis (see Figure 1). The observed declines raise the question as to what role, if any, fire sales might have played in propagating price declines.

This paper makes three important contributions on the question of whether there were fire sales in the RMBS market. We demonstrate conceptually that some financial institutions had incentives to sell RMBS at fire sale prices. We then show empirically that capital-constrained insurance companies subject to mark-to-market accounting sold RMBS at a discount and that prices of these RMBS exhibit subsequent reversals. These pricing patterns (discounts and subsequent reversals) do not appear in the transactions of insurance companies that are not constrained or not subject to mark-to-market accounting. Finally, we find that the known indicia of fire sales are present in the RMBS market during the financial crisis. Specifically, fundamentals perform poorly in explaining RMBS prices during the crisis while they do well before and after the crisis; there is evidence of a rebound in prices after the crisis; and, finally, investors with more expertise in RMBS appear to be sidelined during the crisis.

We consider first why financial institutions with a diversified portfolio of liquid assets would sell RMBS into an illiquid market. When there is a need to raise capital, as was the case during the crisis, a financial institution generally wants to sell assets that have the lowest selling cost, i.e., assets where the

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

[2] 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. "The origins of the financial crisis: Crash course," The Economist, September 7, 2013.

sale involves the smallest discount from fundamentals. However, the selling decision is considerably more complicated with risk-sensitive capital requirements and mark-to-market accounting. 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] Hence, a financial institution may be better off, if it faces capital constraints, to sell downgraded assets, even at fire-sale prices in order to recover capital. However, the financial institution's decision is further complicated by accounting rules. If securities are not accounted for on a mark-to-market basis for the computation of regulatory capital, they are typically held by a financial institution at a price that is much higher than the market price during a crisis. Consequently, absent mark-to-market accounting, the institution makes a large loss when it sells a downgraded security and will in general not sell such securities. If the security is mark-to-market, the only loss is the one associated with a discount from the estimate of the market value of the security, which is effectively the fire sale discount. Our hypothesis, then, is that the combination of risk-sensitive capital requirements and mark-to-market accounting rules creates incentives for financial institutions to sell financial assets into distressed markets, even, potentially, at fire sale prices. We outline the mechanics of our hypothesis in Section 1 and provide a detailed numerical example in the appendix.

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. Empirical tests of our hypothesis are highlighted by two sets of results. First, we provide evidence that firms exposed to adverse capital shocks sold downgraded RMBS at discounts relative to other sellers, controlling for fundamentals. Moreover, adverse shocks to capital only create fire sale discounts when firms are subject to mark-to-market

[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.

accounting rules.[4] We find that the RMBS sales of "constrained firms" occur at fire sale discounts of 5% to 25%, depending on the specification.[5]

If fire sales actually occur, they are generally followed by price reversals. Our second key empirical result is to show that the RMBS that traded at the largest discounts during the crisis, those we identify as having occurred at fire sale prices, were associated with the largest subsequent price reversals. This result is particularly interesting because the aggregate RMBS market demonstrated price reversals coming out of the crisis. However, the fact that the data reveal differential magnitudes of price reversals is further evidence that some transactions originally occurred at fire sale discounts.

Our key results document fire sale discounts and subsequent price reversals, but we also provide supplementary evidence that the RMBS market in aggregate showed the hallmark signs of a market with fire sales. Shleifer and Vishny (1992) demonstrate that fire sales exist when natural arbitrageurs are unable to fulfill their traditional role of correcting market mispricing. Consistent with the lack of natural arbitrageurs, we find evidence of heightened volatility of pricing errors during the crisis. Finally, we provide somewhat limited evidence of sidelined natural buyers, another prominent feature in theories of fire sales.

Fire sales are not the only potential explanation for the observed decline and subsequent rebound in RMBS prices through and after the crisis. Other possible explanations include a decline in mortgage fundamentals, highlighted by a spike in mortgage default rates at the peak of the crisis. Closely related to mortgage fundamentals is the role of market expectations. Price declines and subsequent reversals could be explained by evolving market expectations, a notion that is difficult to test empirically. Discounted transaction prices could also be evidence of idiosyncratic price pressure in a thin market, as opposed to systematic fire sales. While these explanations are potentially valid, and may have impacted prices, we

[4] There has been much debate about whether fair value accounting standards made the impact of fire sales worse. 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.

[5] We use the somewhat ambiguous term "constrained firm" to refer to firms that have experienced an adverse shock to their capital and that are subject to mark-to-market accounting practices.

find evidence consistent with a unique role of capital requirements and mark-to-market accounting rules in explaining time-series variation in observed RMBS transaction prices.

Our hypothesis maintains that risk-sensitive capital requirements can act as a mechanism to induce forced sales. If true, market participants in an adverse capital position should have the strongest incentive to sell downgraded RMBS. However, observing in the data that poorly capitalized firms sold downgraded RMBS at a discount does not allow for a causal inference regarding the impact of capital on fire sales, because downgraded RMBS themselves could impact a firms' capital. In fact, the endogeneity is particularly pernicious because, aside from the simultaneity problem just described, unobserved omitted variables could influence collateral selection decisions that could jointly impact a firms' subsequent capital position and subsequent collateral prices.

We deal with the simultaneity problem (low capital causing fire sales or fire sales causing low capital) by sorting firms based on an aspect of their operating business that influences their capital position that should not be directly correlated with the performance of RMBS. Firms that have experienced a negative shock to their insurance business, as evidenced in their operating cash flows in the year prior to an observed RMBS transaction, have experienced an adverse capital shock for reasons other than poor performance in their RMBS portfolio.[6] We show that negative operating cash flow shocks in connection with downgraded credit ratings on RMBS leads to lower RMBS prices, all else equal, including, importantly, fundamentals of the mortgage collateral.

While the use of one-year lagged negative operating cash flows plausibly addresses a simultaneity problem, it does not rule out a potential omitted variable that could be driving a correlation between negative operating cash flows and low RMBS prices. Put differently, the use of negative operating cash flow shocks as a proxy for an adverse shock to regulatory capital satisfies the relevance criterion but does not satisfy the exclusion restriction. The actions of firm management could jointly influence a firm's operating cash flows and the quality of RMBS in the asset portfolio. As an example, Koijen and Yogo

[6] Income from investments such as RMBS is not accounted for in the operating cash flows that we use as a proxy for shocks to capital. Thus, strictly from an accounting standpoint, one-year lagged operating cash flows are exogenous to economic capital.

(2014) document that managers' actions can influence both the operating performance of a firm and the firm's asset/liability management. Specific to our setting, bad management could cause both negative operating cash flow and poor-quality RMBS that are subsequently downgraded and sold at discounts.

In order to rule out a "bad manager" hypothesis (or other time-invariant omitted variables), we rely on a difference-in-differences specification across a rule change introducing mark-to-market accounting to life insurance firms in 2009. Mark-to-market accounting will exacerbate the cost of holding downgraded RMBS because it forces firms to recognize a loss conditional on a downgrade to a rating with a higher capital charge.[7] In our sample of insurance firms, Property & Casualty (P&C) insurers were subject to mark-to-market accounting over our full sample while life insurers began adhering to mark-to-market accounting in 2009.[8] The change in accounting standards for life insurers allows for a comparison of life firms to P&C firms before and after the accounting change. We find that life insurers sell downgraded RMBS at significantly discounted prices in 2009, though not before, as compared to their P&C counterparts whose behavior was consistent throughout the sample period. The difference-in-differences strategy allows for the identification of capital and mark-to-market accounting as a feature driving fire sales as opposed to a time invariant "bad manager" hypothesis. We emphasize, importantly, that our identification strategy relies on the combination of negative operating cash flow shocks *and* a change in regulatory accounting standards for a segment of insurance companies.

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 document the price impact of forced sales. In Section 4 we investigate price reversals and in Section 5 we evaluate the broader market for RMBS and find that it exhibits two additional indicators of fire sales; increased unexplained price variability and natural buyers being out of the market. We conclude in Section 6.

[7] Absent mark-to-market accounting, firms would only have to recognize the downgrade through an increase in regulatory capital.

[8] We detail the specifics of life companies' adherence to mark-to-market accounting, including their reliance on and the timing of "marking-to-model" practices in Section 1.2.

Section 1. Hypothesis Development

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.[9] 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

[9] 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.

institution would want to sell assets that have low selling costs – i.e., the lowest discount from fundamentals.[10] 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 requirements 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.[11] 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)).[12] 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 are likely to be industry specialists. Industry specialists operate in the

[10] 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.

[11] 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.

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

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.[13] 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 affect 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, as when fair value accounting is used, an institution that had enough capital before the write-downs may not have enough capital after the write-downs, especially when additional

[13] 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.

capital is required for impaired securities, 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 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 hold 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.[14] 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, property and casualty (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

[14] 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.

only required to use mark-to-market accounting for NAIC level 5 or 6 securities.[15] 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 of 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 over our full sample period, which is Q1 2007 through Q3 2009.

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

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.

It is important to clarify that the fire sale mechanism we focus on does not require that an insurance company is about to breach its minimum capital requirement. Instead, what is required it that its capital situation worsens in such a way that it becomes advantageous for the firm to take steps to bolster its regulatory capital. A firm's capital situation might be costly to it because it no longer has enough of a buffer relative to its minimum capital requirement. Such a required buffer can arise because a firm may want to make sure that adverse shocks leave it room to operate or because external parties, such as customers, rating agencies, or investors, expect the firm to have such a buffer.

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 are 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 when such sales would relax regulatory capital 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. In addition, 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. Lastly, within the broader context of their analysis of nonstandard ABS markets, Chernenko, Hanson, and Sunderam (2014) briefly consider fire sales. They do not find evidence of increased transaction volume in nonstandard ABS during the crisis, which they interpret as a lack of evidence for fire sales in this market.

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

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. The data file contains unique transactions that span the years 2000 through 2012. 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.

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.[16] 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.[17]

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. NAIC data is available for the years 2006-2010. We match insurance company attribute data from NAIC and AM Best to the RMBS transaction file by insurance company name.

Matching the insurance company file to the RMBS transactions and collateral attributes files results in the loss of a number of insurance companies. This occurs for two reasons. First, collateral attributes are not available for every RMBS transaction. Second, the matching of insurance company data to RMBS

[16]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.

[17] We use MSA- and state-level indexes when ZIP-code indexes are unavailable.

transaction data occurs by hand. We are unable to find insurance company names in the insurance database for many of insurance company names listed in the RMBS transactions. We are sensitive to whether the insurance companies that remain in the sample are representative. We demonstrate in Table 3 that the sub-sample of insurance companies that remain in the sample demonstrate similar patterns as those we lose in the matching process.

Section 2.2. The Use of a Repeat-Transaction Sample

Fire sales can be defined as forced sales that result in deviations in price from an asset's fundamental value. An important feature of our analysis is that we control for the fundamentals of the mortgage collateral in an RMBS, which allows us to analyze RMBS prices relative to fundamentals. We can also control for credit ratings at the time of a transaction. Unfortunately, RMBS contain a host of institutional features that also impact their price in important ways that are not captured in ratings or mortgage collateral attributes. These features include seniority in the capital structure of a deal, performance triggers, differences in pre-payment treatment, and other unobserved features. As a means of controlling for these unobserved features, our analysis relies on a repeat sales 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. We do not require that the transaction pairs are associated with the same firm. If an RMBS has N unique transactions, we calculate N-1 unique transaction pairs. In our estimation of fire sales, we require that the second transaction in a second transaction pair be a sell transaction.

Section 2.3 Estimation Samples

The empirical tests in this paper rely on three unique samples that differ in their unit of analysis and time period. The three samples are the "fire sales" sample, the "reversals" sample, and the "natural buyers" sample. We briefly discuss the features of each sample.

The "fire sales" sample is estimated on transactions when the second transaction in a transaction pair occurred between Q1 2007 and Q3 2009. It begins in 2007 because our identification strategy requires measuring the lagged operating cash flows of the insurance companies involved in sell transactions. Our earliest operating cash flow data is available in 2006. The sample runs through Q3 2009 because life insurance companies were likely to begin marking-to-model sometime near the end of 2009 or beginning of 2010 (as described in Section 1.2). The unique intersection of collateral attribute data, RMBS transactions, and insurance company attribute data limits the sample to 1,167 repeat sale transactions of 120 unique life firms and 615 repeat sale transactions for 172 P&C firms. The unit of analysis in the fire sales sample is at the RMBS transaction level.

The "price reversals" sample utilizes the full sample of prices from 2000 through 2012, though the estimation sample focuses on repeat transactions where the second transaction occurred between 2006-2012. The reversals sample contains 14,261 repeat sales transactions. The sample is larger than the fire sales sample because we do not require detailed data on insurance company attributes. Rather, the primary data limitation of the reversals sample is data on mortgage collateral attributes. The unit of analysis in the reversals sample is also at the RMBS transaction level.

In the "natural buyers" sample we evaluate the purchasing patterns of insurance companies between the years 2006 and 2012. The unit of analysis is also at the transaction level but the estimation strategy does not rely on a repeat sales sample. Our controls are insurance company controls because we are interested in explaining the attributes of insurance companies involved in the purchasing of RMBS. The estimation sample runs from 2006 through 2012 because those are the years for which we have relevant insurance company attributes. The sample involves 28,544 unique transactions and is larger than the other samples because it does not require repeat sales transactions.

Section 2.4 Summary statistics

Table 1 reports summary statistics on the prices of RMBS transactions from 2006 through 2012. We also report summary statistics on the changes in prices that are calculated using the repeat transaction

sample. Table 1 also tabulates the percent of transactions that were sell transactions as well as the average mortgage default rate in the month prior to a transaction. The table clearly documents the decline in RMBS prices through the crisis period, as well as the increase in mortgage collateral default rates. In Section 4 we analyze price reversals in the RMBS market and focus in more detail on the broad RMBS pricing patterns documented in Table 1.

Table 2, panel A, provides high-level summary statistics of the insurance companies involved in RMBS transactions. Our sample contains more unique P&C firms than life, though the life firms are substantially larger in size than P&C firms. Differences in size and product offerings explain why life firms hold substantially more RMBS than P&C firms in our sample. Life firms have higher levels of regulatory-based capital, reporting median RBC ratios over 8 as compared to RBC ratios closer to 6.5 on average for P&C firms.

Panel's B and C of Table 2 report data on the credit rating patterns of the RMBS in our sample. Horizontal columns represent the S&P credit ratings as of the first transaction in a repeat transaction pair while vertical columns represent the credit ratings as of the second transaction in a repeat transaction pair. Each cell of the table represents counts of RMBS within the corresponding ratings. The tables are tabulated only for the transactions with adequate data to be included in our fire sales estimation sample.[18] We report tables separately for the P&C and life samples. In the life sample, of the 605 transactions that were originally rated AAA, 85 were subsequently downgraded, 75 of which were downgraded sufficiently to cross an NAIC ratings threshold (e.g., NAIC 1 to NAIC 2). The P&C sample exhibits similar patterns. The patterns reported in Table 2 are not necessarily representative of downgrade patterns in the broad RMBS market because we report ratings transitions of RMBS conditional on the RMBS being involved in at least two transactions with the second transaction being a sell.

[18] Numbers reported in the transition matrixes will not sum to the exact number of observations in our estimation sample. This is because our estimation sample is supplemented with Moody's ratings for the purposes of evaluating whether a bond was downgraded. We only report the transition matrices for S&P ratings in the summary statistics to maintain consistency in ratings standards.

Section 3. Identifying Fire Sales

Section 3.1 Motivating the Identification Strategy.

Identifying a causal link between low levels of capital at insurance companies and RMBS transactions that occurred below fundamental value is a challenge because of two potential sources of bias: simultaneity and omitted variables. Regulatory capital constraints could induce firms to sell downgraded RMBS at fire sale prices, but regulatory capital constraints could themselves be caused by downgraded RMBS. Because of this possibility, we propose a specification designed to disentangle the endogenous relationship between firm capital and RMBS credit quality.

For conceptual purposes, consider a naïve, linear model of the following form:

$$Chg\ Price_{i,t-1\rightarrow t} = \alpha + \beta \cdot Capital\ Position_{j,t} + \delta X_{i,t} + \varepsilon_{i,t}, \qquad (1)$$

where the variable *capital position* captures the capital position of firm *j* at time *t. Chg. Price* captures the change in price of RMBS *i* between two consecutive transactions. *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 institutional features of RMBS. 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.

Careful estimation of the economic relationship proposed in equation (1) requires a variable that is correlated with the capital position of a firm but not correlated with the performance of the RMBS portfolio. We propose using negative shocks to a firm's operating cash flow in the year prior to an observed RMBS transaction as an exogenous proxy for the capital urgency of a firm. Cash flow from operations essentially represents an insurance company's underwriting income.[19] As such, negative cash

[19] An example of an event that could precipitate a negative cash from operations year for a property and casualty insurer is a catastrophic loss in a given year. Insurance companies create a reserve from which losses are paid based upon actuarial estimates of losses. In a year with, for example, a surprise level of losses due to a hurricane, tornado, or surprise verdict in a liability lawsuit, an insurer could experiences losses that are greater than the reserve that was created to pay those losses. That event could trigger a lower, or even negative, increment to cash from operations. This income statement item is above investment gains or losses and is likely to be uncorrelated with RMBS losses.

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. For life firms, operating income is the most relevant measure of a true shock from the operations of the business. For P&C firms, underwriting income is a more accurate measure of a shock from operations. For consistency in the exposition, we refer to both of these measures as operating income shocks.

Though lagged negative cash flow shocks should be correlated with the capital position of an insurance company, and plausibly address the simultaneity problem, they do not completely satisfy the exclusion restriction. The use of lagged negative operating cash flows introduces the possibility of an omitted variables problem because negative cash flow shocks could be correlated with unobserved management attributes that could jointly influence the selection of poor-quality RMBS in the investment portfolio and poor operating performance of the firm (the kind of poor operating performance that results in negative operating cash flow). For this reason, our identification strategy requires an additional step. We rely on changes in the mark-to-market accounting treatment for life firms that came into effect in 2009 (see Section 1.2 for a detailed description) and estimate whether this change impacted the life transactions differently than P&C transactions, whose accounting treatment did not change over this period. By exploiting the accounting rule change, for an unobserved "bad management" bias to be of concern, it would have to be uniquely correlated with P&C firms that experienced downgrades over the entire sample period but only life insurance companies that experienced downgrades in 2009.

And, a negative increment to cash from operations is covered by a decline in capital. Merrill, Nadauld and Strahan (2014) present a macro shock to the life insurance industry that creates analogous pressure on capital for life insurance firms.

Section 3.2. Operating Cash Flow and Capital.

Firms that experience a negative operating cash flow shock in year *t-1* should see a reduction in regulatory capital in year *t*. In this section we evaluate whether this assertion is true in the data. We calculate the year-over-year change in risk-based capital ratios for the insurers in our sample and regress the RBC change on a negative operating cash flow indicator. The negative cash flow indicator is equal to one if the firm experienced negative cash flows in the prior year. We evaluate RBC changes for the sample period 2007-2009 to correspond with the sample period in our fire sales sample.

Table 3 reports the results. Columns (1) & (2) evaluate a sample that includes all insurance companies for which we have RBC, asset size, and operating cash flow data.[20] The coefficient on the negative cash flow indicator is a statistically significant -0.185 without control variables included in the regression and is -0.346 when controls are included. We then estimate the same regression using only the insurance companies that are included in our fire sales regressions. The estimates using the two samples are very similar, indicating that the insurance companies for which we have adequate data to estimate the fire sales regressions adequately capture the cash flow-RBC relationship. The estimate on the negative cash flow shock indicator in Column (4), reported as -0.308 with a t-statistic of 2.10, indicates that firms that experienced a negative cash flow shock in the prior year are associated with a 0.3 units reduction in regulatory capital (i.e. RBC*t-1* = 6 compared to RBC*t* = 5.7). The average year-over-year change in RBC is 0.16 with a standard deviation of 1.8. Thus, the lagged negative cash flow indicator predicts a 1/6 standard deviation decline in RBC. The economic magnitude is likely understated however because we are using a negative cash flow indicator as opposed to a measure of the full magnitude of negative cash flow shocks. We use an indicator rather than the magnitude of cash flow shocks in the regressions to

[20] We label this sample as the "full insurance company sample" in Table 3. This sample includes substantially more insurance companies than are included in our fire sales sample because the fire sales sample requires matching firms to the RMBS transactions database as well as the collateral attribute database.

facilitate ease in interpreting the results. Overall, the results indicate that negative cash flow shocks predict economically meaningful subsequent declines in risk-based capital.[21]

Section 3.3 Downgrades and Operating Cash Flow Shocks.

Our hypothesis maintains that risk-based regulatory capital creates an incentive for firms to sell downgraded securities, even potentially at fire sale prices, if firms are in an adverse capital position. We test this hypothesis by evaluating the RMBS sale prices of downgraded securities for firms that have been exposed to a negative operating cash flow shock in the year prior an observed transaction. Table 4 presents results.

The dependent variable in our tests is calculated as the change in price from a previous transaction given that the second transaction is a sell.[22] Two indicator variables are of interest in the table. The first named *neg. cash flow shock indicator* is equal to one if a firm experienced negative cash flows in the year prior to an observed transaction. The second variable of interest, named *downgraded bond indicator*, is equal to one for an RMBS that has been downgraded sufficiently to cross a NAIC ratings-category threshold. Downgrades that span a NAIC rating category will correspond to substantial increases in risk-based regulatory capital treatment. An example of a downgrade that spans a NAIC ratings category would be a downgrade from a AAA rating to a BBB rating (see the appendix for more detailed examples). We

[21] One potential limitation with this result is that the documented relationship between regulatory capital and operating income could be contaminated by the financial crisis. While the model contains year fixed effects, potentially capturing crisis effects, ideally we would evaluate the RBC-operating income relationship in a full sample period outside of the crisis. Unfortunately the data are not available. One remedy is to evaluate the RBC-operating income relationship in the year 2007, where 2006 operating cash flows are used to evaluate changes in RBC between 2006 and 2007. This period should not be contaminated by the crisis because operating income is measured prior to the crisis and prices of RMBS had not yet experienced dramatic declines. The results using this sub-sample are qualitatively similar to those reported in the full sample.

[22] 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.

control for a host of collateral attributes and quarter fixed-effects and cluster standard errors by insurance company.[23] The inclusion of firm fixed effects ensures that estimates are not unduly influenced by the selling activities of any one firm in particular.

Column (1) of Table 4 indicates that negative operating cash flow P&C firms are associated with virtually no decline in price between two repeat transactions. As expected, downgraded bonds are associated with substantial declines in RMBS value, 12.8% in the case of P&C firms (also column (1)). Column (3) reports results for life firms. Results for downgraded bonds are similar to the P&C sample, estimates indicate a 17.8% decline on downgraded bonds, while the negative operating cash flow indicator is not significant economically or statistically.

Our hypothesis predicts that the combination of downgrades and adverse capital is where fire sales should be most pronounced, which can be evaluated with an interaction of the negative operating cash flow indicator with the downgrade indicator. The coefficient on the interaction term reported in Column (2), -0.284, with an associated t-statistic of 2.35, suggests that negative operating cash flow P&C firms sell downgraded bonds at a significant discount to downgraded bonds sold by positive operating cash flow firms. The total effect of being a downgraded bond and having experienced an operating cash flow shock appears to be about 32% (-0.284 - 0.075 + .038).

Recall that P&C firms adhered to mark-to-market accounting over the full sample while life firms began marking-to-market in 2009. As such, we would expect downgrades not to have as large of an effect for life firms over the full sample, but that the effect should be concentrated in transactions occurring in 2009. Column (4) of Table 4 confirms that the combination of downgrades and negative cash flow shocks are not associated with statistically significant pricing discounts for life firms, though downgraded bonds themselves continue to sell at substantial discounts.

[23] All the results in our paper are robust to clustering standard errors by month of transaction, or by both firm and month of transaction.

Section 3.4. Mark-to-Market Accounting, Downgrades, and Cash Flow Shocks

Results presented in Table 4 indicate that cash flows shocks and downgrades were associated with substantial pricing discounts on RMBS for P&C firms but not life firms. In this section we exploit the change in accounting treatment for life firms in 2009 and test whether adherence to mark-to-market accounting treatment resulted in fire sale discounts. The rule change allows for a comparison of the downgraded/cash-flow shock interaction term before and after 2009 for P&C and life firms. We expect no difference in discounts for P&C firms before and after 2009. In contrast, downgrades and cash-flow shocks should result in larger discounts for life firms after 2009 compared with pre-2009 transactions. We construct an additional indicator variable named "2009 indicator" that is equal to one for all transaction-pairs where the second transaction occurred within the first three quarters of 2009.[24] The 2009 indicator is interacted with the negative cash flow shock and downgrade indicators.

Column (1) of Table 5 reports results for the P&C firms and Column (2) reports results for life firms. As in Table 4, the model includes firm fixed effects. The coefficient on the three-way interaction term for P&C firms is not statistically different from zero, indicating that the downgrade/cash-flow shock discount was not statistically different in 2009 as compared to pre-2009. Life firms, however, demonstrate a substantial difference in downgrade/cash-flow shock discounts after 2009. The statistically significant coefficient of -0.469 indicates that the transactions of negative operating cash flow firms selling downgraded RMBS after 2009 were at a deep discount as compared to similar RMBS transactions prior to 2009. The total fire sale effect, found by summing the coefficients on each of the interaction terms and stand-alone indicators suggests fire sale discounts of about 4% for life firms. When estimated without firm fixed effects, the estimates indicate fire sale discounts of 15% for life firms. Importantly, fire sales for life firms appear most concentrated in 2009 when mark-to-market accounting was in effect, as opposed to P&C firms who appeared to be involved in fire sales over the full sample. This evidence appears to be at odds with a time-invariant bad manager hypothesis. Bad managers could be the source of

[24] As discussed earlier, the adoption of marking-to-model rules took effect late in 2009. We therefore constrain our mark-to-market event to the first three quarters of 2009.

negative operating cash flows and poorly-performing RMBS portfolios, but such a correlation is unlikely to be present for life firms only in 2009 but not in 2007 and in 2008, yet present for P&C firms over the whole sample period.

Section 4. Price Reversals

Section 4.1. Evidence of Price Reversals

In addition to forced sales, a market experiencing fire sales should also exhibit 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.[25] 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

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

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 price reversals comes in an analysis of changes in RMBS prices using the repeat transaction sample. Our sample of repeat transaction pairs begins with transactions as of January 2006 and runs through December 2012. We construct two indicator variables of interest. The first indicator, named *spans beginning of crisis,* is equal to one for the change in price between paired-transactions where the first transaction occurred prior to the crisis and the second occurred during the crisis.[26] We further require that the first transaction is a purchase and the second transaction is a sell. The second variable of interest, named *spans end of crisis,* is equal to one for the change in price between transaction pairs where the first transaction occurred during the crisis and the second after the crisis. We also require the transaction during the crisis to be a sell and the post-crisis transaction to be a purchase. The indicator variables allow for an analysis of broad price changes going into the crisis and price reversals coming out of the crisis. We also include firm fixed effects.

Table 6 reports results of an OLS regression where the change in price is estimated on the *spans beginning of crisis* and *spans end of crisis* indicators. The results in Column (1) indicate that prices declined an average of 17.4% heading into the crisis, and rebounded an average of 14.4% coming out of the crisis. The results do not control for the impact of mortgage fundamentals however. Column (2) reports results when controlling for our standard mortgage fundamentals variables, including an indicator

[26] We define the crisis period as Q3 2007 through Q3 2009 as it corresponds to the time period of declining RMBS prices.

for downgraded RMBS. Controlling for fundamentals reduces the magnitude of the *spans beginning of crisis* indicator because downgrades and increases in default rates are so highly correlated with RMBS pricing declines heading into the crisis. The *spans end of crisis* indicator continues to indicate pricing rebounds coming out of the crisis, even when controlling for fundamentals.

Section 4.2. Do Price Reversals Simply Reflect a Change in Market Expectations?

A plausible explanation for the observed pattern of price declines and subsequent reversals, as opposed to our proposed fire sales explanation, is a "changing-expectations" hypothesis. A changing-expectations hypothesis argues that price declines heading into the crisis were the result of the substantial decline in mortgage market fundamentals and of expectations of high default rates in the future. These expectations might have been too pessimistic and might have become more positive as the business situation improved and various government programs kicked in.

A changing expectations hypothesis is inherently difficult to test empirically given the exceptional circumstances surrounding the financial crisis. However, we can evaluate patterns in pricing reversals for the transactions identified as fire sales in section 3. While the changing expectations hypothesis likely played an important role in price reversals, a change in the market's expectations is not likely to be uniquely correlated with the transactions of negative operating cash flow insurance companies selling downgraded RMBS.

We evaluate price reversals on the fire sale transactions by creating an indicator variable called *constrained transaction indicator*. This variable identifies the transactions that were associated with fire sales in section 3 – i.e. the sell transactions of negative operating cash flow P&C firms between Q1 2007 and Q3 2009 and the sell transactions of negative operating cash flow life firms between Q1 2009 and Q3 2009. This criterion captures 138 unique constrained transactions. The variable *constrained transaction indicator* is equal to one when the constrained transaction is the second transaction in a transaction-pair. By construction, the variable *constrained transaction indicator* should provide an estimate of the fire sale discounts associated with the constrained transactions during the crisis. We also construct an interaction

term named *spans end of crisis*constrained transaction indicator* that is designed to estimate changes in price when the constrained transaction is the first transaction in a transaction pair and the second transaction occurred after the crisis. The interaction term should estimate the magnitude of price reversals of the transactions that originally sold at fire sale prices.

Columns (3) and (4) of Table 6 report estimates associated with these variables. The coefficient on *constrained transaction indicator* in Column (3), a statistically significant -0.254 suggests pricing declines of over 25% in the crisis. This estimate is slightly larger, though generally consistent with fire sale magnitudes reported in Tables 4 and 5. Column (4) reports a coefficient on the *spans end of crisis*constrained transaction indicator* interaction of 0.233, with associated t-statistic of 2.87. This estimate suggests that changes in price of RMBS where the first transaction was constrained subsequently rebound 23.3% higher than comparable transaction-pairs that also spanned the end of the crisis where the first transaction was not constrained. This estimate is consistent with substantial price reversals of RMBS that originally sold at fire sale prices.

Overall, the results provided in Table 6 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. Additionally, price reversals were significantly larger for transactions that we identified in Section 3 as originally having sold at fire sale prices. While these results do not rule out a changing-expectations hypothesis, a factor likely at play in RMBS pricing rebounds, our estimates do provide positive evidence of substantial rebounds in those transactions identified to have occurred at fire sale prices in Tables 4 and 5. The *differences* in the magnitude of reversals between the broad market and those associated with fire sales are not likely explained solely by a changing-expectations hypothesis.

Section 5: Heightened Pricing Errors and Lack of Natural Buyers

In this section, we present broad, macroscopic evidence that indicates that the pricing discounts and price reversals documented in the previous section took place in an environment that demonstrates the hallmark signs of fire sales in the broader RMBS market. One reason to consider other types of fire sales

evidence is the possibility that the results documented in the previous section are evidences of microscopic, one-off forced sales of RMBS that cause price pressure, resulting in price discounts as opposed to fire sales.

In addition to forced sales and reversals, Shleifer and Vishny (2011) identify at least two other indicators of fire sales that have been explored in the literature. These are the exit of natural buyers and violations of arbitrage conditions. None of these additional two indicators are individually dispositive in isolation and, in fact, they are interconnected. In this section, we present evidence of increased idiosyncratic variation and of natural buyers leaving the market.

Section 5.1. Evidence of greater unexplained cross-sectional variation in prices.

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 5.2. 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 7 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.[27] 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.

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

In Columns (3) and (4) of Table 7 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 7 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. Admittedly, the interpretation of these results should be tempered by the fact that we do not have purchasing data on banks and other financial institutions, which were also substantial buyers of RMBS. That said, variation in purchasing activity within the cross-section of natural purchasers within the insurance industry 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 6. 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. Our results help better understand how capital requirements and accounting rules affect the decisions of financial institutions to sell assets. Further, 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.[28]

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.

[28] 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.

Though our analysis employs data from insurance companies, our results have broad implications for financial institutions of all types. Specifically, 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.

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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 14,602 unique transactions are averaged within a given month.

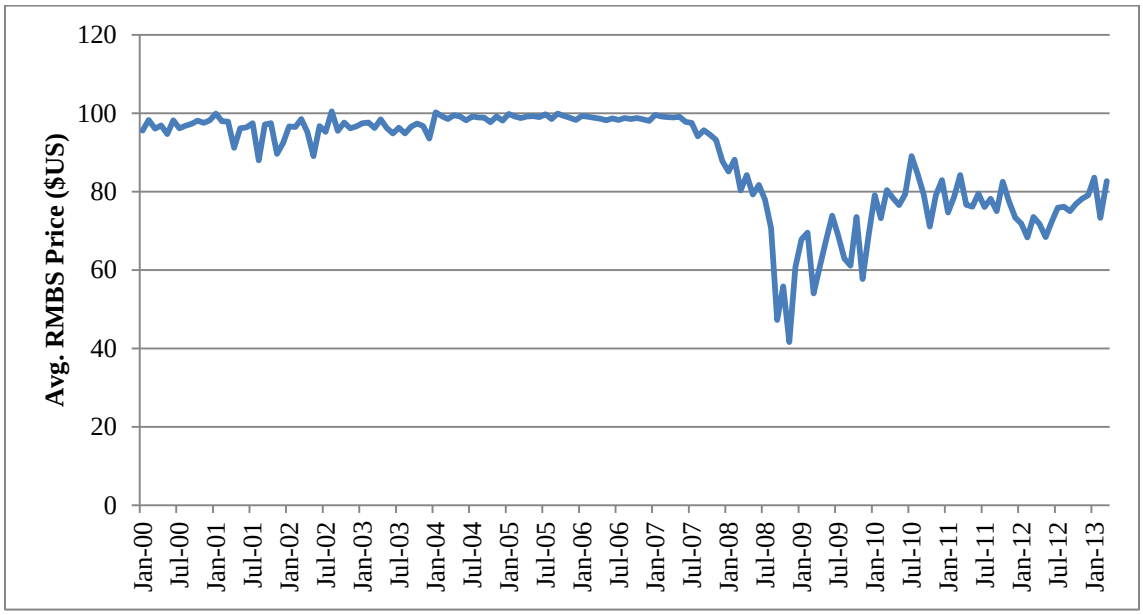

Figure 3. Average RMBS Pricing Residuals

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.

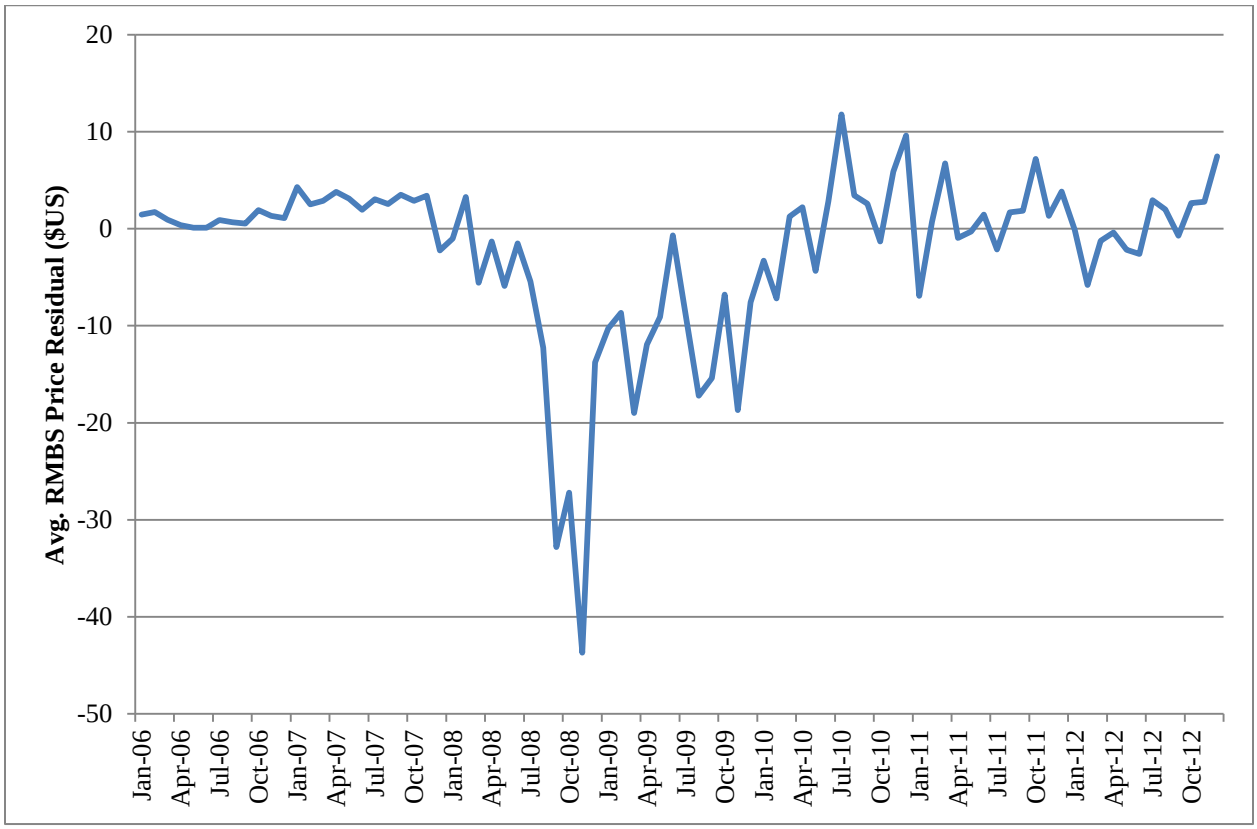

Figure 4. Three-month Moving Average of the Standard Deviation in RMBS Pricing Residuals

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 (same regression that is estimated to produce Figure 3). 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.

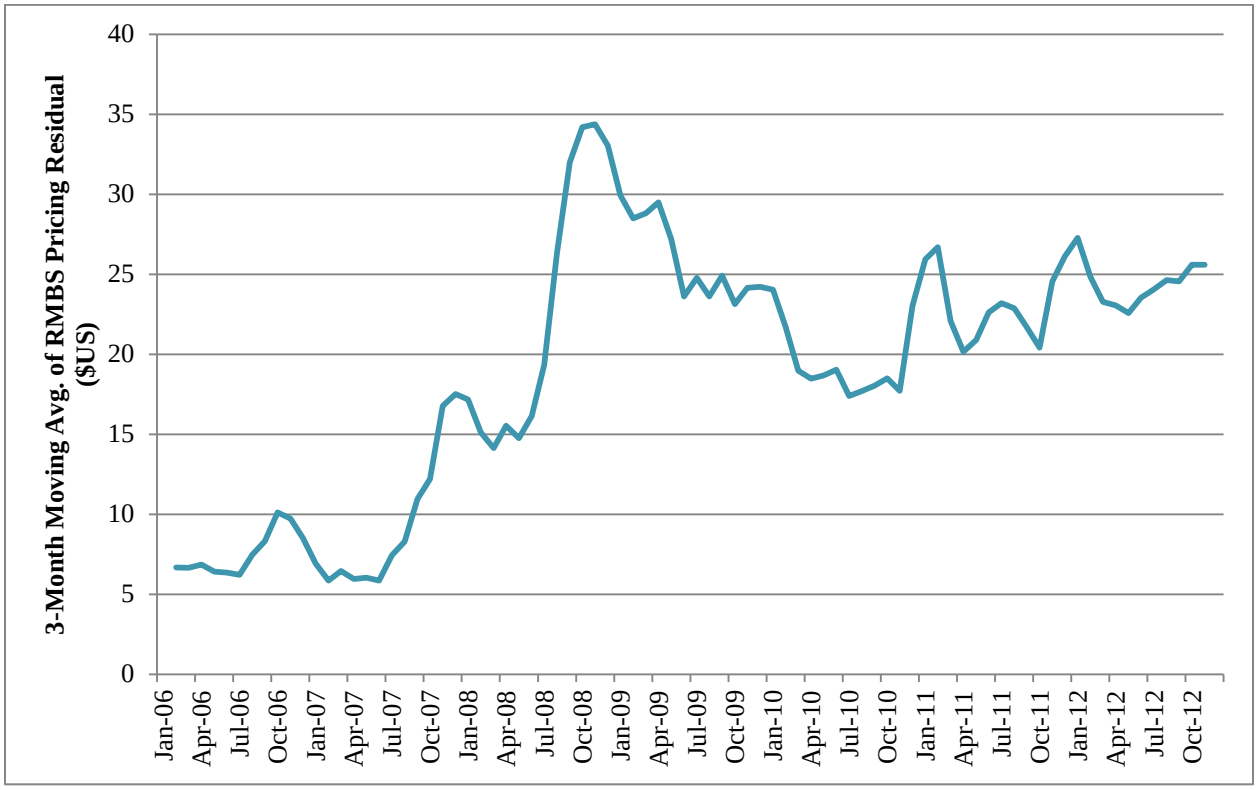

Table 1. Summary Statistics.

The RMBS transaction sample includes RMBS 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. Summary statistics are based upon the date of the second transaction. 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. Summary Statistics.

Panel A of this table provides summary statistics on the insurance companies whose RMBS transactions are evaluated in the paper. The table reports statistics in the years 2007, 2008, and 2009 because these are the years included in the sample for the main fire sales specifications. Panels B and C report credit ratings transition matrices. The vertical columns represent the S&P credit ratings at the time of the first transaction in a transaction pair. The horizontal rows ratings represent ratings as of the second transaction. For example, for Life insurers as represented in Panel B, 605 transactions were rated AAA as of the first transaction. Of those 605 originally-rated AAA, 21 were rated B as of the second transaction.

Panel A. Summary Stats on Insurance Companies

	P&C Insurers	Life Insuers
	(1)	(2)
Number of Firms	172	120
Number of Firms with lagged negative operating cash flow:		
2007	24.5%	38.4%
2008	24.6%	35.7%
2009	26.2%	22.7%
Average Assets (Millions of Dollars):		
2007	$2,260	$19,100
2008	$2,150	$20,000
2009	$2,190	$20,000
Median RBC Ratio:		
2007	6.82	8.38
2008	5.71	8.58
2009	6.57	8.52

Panel B. Life Insurance Credit Ratings Transition Matrix

	Rating After Downgrade								
Initial Rating	AAA	AA	A	BBB	BB	B	CCC	CC	D
AAA	520	2	8	3	13	21	31	4	3
AA		158	1	1	2	4	11	8	2
A			163	7	5	3	12	9	12
BBB				48	2	4	4	3	6
BB					9	1	0	1	1
B						12	2	0	0
CCC							15	0	0
CC								1	0
D									5

Table 2 continued….

Panel C. P&C Insurance Credit Ratings Transition Matrix

	Rating After Downgrade								
Initial Rating	AAA	AA	A	BBB	BB	B	CCC	CC	D
AAA	393	2	5	5	3	12	11	0	0
AA		46	0	0	0	1	6	3	1
A			13	1	0	0	2	0	2
BBB				9	3	5	4	0	1
BB					8	0	1	0	2
B						16	8	0	0
CCC							12	1	1
CC								3	0
D									3

Table 3. Do Negative Operating Cash Flows Predict Declines in Regulatory Capital?

This table estimates OLS regressions using insurance company data on regulatory capital and operating income. The unit of analysis is at the insurance company level. The dependent variable, *Annual change in RBC*, is calculated as the change in the regulatory risk-based capital (RBC) ratio for a given insurance company over a given year. The sample period runs from 2007-2009. Changes in the RBC ratio for 2007 are calculated using 2006 RBC levels. *Negative cash flow shock indicator* is equal to one for insurance companies that experienced a negative operating cash flow shock in the prior year. *Log assets* measures the size of the insurance company. RBC_{t-1} is the RBC ratio of the insurance company in the base year of the change in RBC calculation. *Life insurer indicator* is equal to one for life insurers and is equal to zero for P&C insurers. The model includes year fixed-effects. Standard errors are clustered by firm.

	Dependent Variable: Annual Change in RBC (RBC_t - RBC_{t-1})			
	Sample: 2007-2009			
	Full Insurance Company Sample		Fire Sale Estimation Sample	
	(1)	(2)	(3)	(4)
Neg Cash Flow Shock Indicator	-0.185***	-0.346***	-0.279*	-0.308**
	(-3.458)	(-6.151)	(-1.884)	(-2.103)
Log Assets		-0.003		-0.074*
		(-0.237)		(-1.839)
RBC_{t-1}		-0.100***		-0.066***
		(-13.362)		(-3.609)
Life Insurer Indicator		-0.119*		0.078
		(-1.750)		(0.483)
Constant	0.203***	1.234***	0.252***	3.295***
	(6.776)	(3.771)	(3.543)	(2.790)
Year Fixed-Effects	No	Yes	No	Yes
Observations	5,847	5,847	730	730
Adj. R2	0.002	0.052	0.005	0.086

Table 4. Estimating Fire Sales in RMBS Transactions.

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 Q1 2007 and Q3 2009. The variable *Neg Cash Flow Shock Indicator* is equal to one if the insurance company selling the RMBS experienced negative operating income in the year *prior* to the sell 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. *Downgraded Bond Indicator* is equal to one if the bond was downgraded sufficient to cross an NAIC ratings threshold (e.g. AAA, AA, or A-rated bond downgraded to BBB-rated or lower (See Section 2.3 and the appendix for more detail)) between the first and second transactions. 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*. *Months from prior trade* measures the number of months between the first and second trade. *Five-year T-bond rate* measures the level of the 5-year T-bond at the time of the second transaction in a transaction pair. The model includes quarter-of-transaction fixed-effects as well as firm fixed effects. Standard errors are clustered by firm. Results are robust to clustering by month, or by both firm and month of transaction.

	Dependent Variable: % Change in Price from Prior Transaction Sample: Q1 2007 - Q3 2009			
	P&C Sample	P&C Sample	Life Sample	Life Sample
	(1)	(2)	(3)	(4)
Neg Cash Flow Shock Indicator * Downgraded Bond Indicator		-0.284**		-0.026
		(-2.357)		(-0.278)
Neg Cash Flow Shock Indicator	-0.001	0.038	-0.059	-0.050
	(-0.005)	(0.322)	(-1.452)	(-0.952)
Downgraded Bond Indicator	-0.128**	-0.075	-0.178***	-0.171***
	(-2.204)	(-1.221)	(-3.383)	(-3.777)
Change in Collateral Quality from Prior Trade:				
Chg. Cumulative Default Rate	-0.391	-0.427	-0.383	-0.378
	(-1.164)	(-1.185)	(-1.447)	(-1.381)
Chg. Cumulative House Price Appreciation	0.002	0.002	0.005***	0.005***
	(1.094)	(0.974)	(4.680)	(4.715)
Chg. Mortgage Rate	0.021	0.022	0.019**	0.019**
	(1.057)	(1.161)	(2.165)	(2.171)
Chg. FICO Score	0.008**	0.008**	0.001	0.001
	(2.186)	(2.205)	(0.580)	(0.603)
Chg. Combined Loan-to-Value Ratio	-0.009	-0.011	-0.003	-0.003
	(-0.540)	(-0.709)	(-0.168)	(-0.164)
Chg. Percentage of A.R.M.'s	0.714***	0.698***	-0.024	-0.021
	(3.180)	(3.450)	(-0.169)	(-0.154)
Chg. Percent of Loans Owner Occupied	0.735	0.708	-0.251	-0.236
	(0.960)	(0.889)	(-0.365)	(-0.348)
Chg. Percent of Loans No Doc./Low Doc.	0.604	0.498	0.824*	0.815*
	(1.093)	(1.009)	(1.871)	(1.896)
Chg. Percent of Refinance Loans	-0.428	-0.718	-0.399	-0.400
	(-0.762)	(-1.403)	(-0.713)	(-0.715)
Chg. in Geographic Concentration	-1.504*	-1.344	0.556	0.556
	(-1.722)	(-1.580)	(0.853)	(0.848)
Months from Prior Trade	-0.002	-0.002	-0.002*	-0.002**
	(-1.215)	(-1.446)	(-1.948)	(-2.014)
5-Year T-Bond Rate	0.070	0.079	-0.007	-0.006
	(1.022)	(1.299)	(-0.197)	(-0.164)
Constant	-0.294	-0.322*	0.084	0.076
	(-1.568)	(-1.881)	(0.861)	(0.813)
Quarter Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Cluster Standard Errors by Firm	Yes	Yes	Yes	Yes
Observations	615	615	1167	1167
Adj. R2	0.656	0.667	0.750	0.750

Table 5. Differences in Fire Sales by Insurance Type Before and After 2009.

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 Q1 2007 and Q3 2009. The variable *Neg Cash Flow Shock Indicator* is equal to one if the insurance company selling the RMBS experienced negative operating income in the year *prior* to the sell 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. *Downgraded Bond Indicator* is equal to one if the bond was downgraded sufficient to cross an NAIC ratings threshold (e.g. AAA, AA, or A-rated bond downgraded to BBB-rated or lower (See Section 2.3 and the appendix for more detail)) between the first and second transactions. The variable *2009 indicator* is equal to one for transactions that occurred after 2009. 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*. *Months from prior trade* measures the number of months between the first and second trade. *Five-year T-bond rate* measures the level of the 5-year T-bond at the time of the second transaction in a transaction pair. The model includes quarter-of-transaction fixed-effects as well as firm fixed effects. Standard errors are clustered by firm. Results are robust to clustering by month of transaction, or by both firm and month of transaction.

	Dependent Variable: % Change in Price from Prior Transaction	
	Sample Period: Q1 2007 - Q3 2009	
	P&C Sample	Life Sample
	(1)	(2)
Neg. Cash Flow Shock Indicator* Downgraded Bond Indicator * 2009 Indicator	-0.223	-0.469***
	(-0.899)	(-3.020)
Neg Cash Flow Shock Indicator * Downgraded Bond Indicator	-0.116	0.196
	(-0.754)	(1.494)
Neg. Cash Flow Shock Indicator* 2009 Indicator	-0.237	0.192*
	(-1.401)	(1.838)
Downgraded Bond Indicator * 2009 Indicator	0.237	0.111
	(1.567)	(1.307)
Neg Cash Flow Shock Indicator	0.102	-0.099**
	(0.914)	(-2.002)
Downgraded Bond Indicator	-0.242**	-0.235***
	(-2.233)	(-3.064)
2009 Indicator	0.038	0.265***
	(0.250)	(3.042)
Change in Collateral Quality from Prior Trade:		
Chg. Cumulative Default Rate	-0.437	-0.352
	(-1.265)	(-1.453)
Chg. Cumulative House Price Appreciation	0.002	0.005***
	(1.539)	(4.441)
Chg. Mortgage Rate	0.015	0.017*
	(0.809)	(1.979)
Chg. FICO Score	0.002	0.001
	(0.495)	(0.562)
Chg. Combined Loan-to-Value Ratio	-0.014	-0.002
	(-0.962)	(-0.108)
Chg. Percentage of A.R.M.'s	0.483**	0.009
	(2.413)	(0.057)
Chg. Percent of Loans Owner Occupied	0.649	-0.046
	(0.822)	(-0.073)
Chg. Percent of Loans No Doc./Low Doc.	0.396	0.842**
	(0.789)	(2.118)
Chg. Percent of Refinance Loans	-0.890*	-0.227
	(-1.699)	(-0.387)
Chg. in Geographic Concentration	-1.103	0.531
	(-1.345)	(0.893)
Months from Prior Trade	-0.002	-0.002
	(-1.286)	(-1.527)
5-Year T-Bond Rate	0.062	-0.013
	(1.131)	(-0.403)
Constant	-0.284	-0.230*
	(-1.403)	(-1.871)
Quarter Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Cluster Standard Errors by Firm	Yes	Yes
Observations	615	1167
Adj. R2	0.685	0.761

Table 6. Evidence of RMBS Price Reversals.

The dependent variable in this OLS estimation is the change in price for a given RMBS between two transactions. The variable *spans end of crisis indicator* is equal to one for transaction pairs when the first transaction is a sell transaction that occurred during the crisis (crisis = Q3 2007 through Q4 2009) and the second transaction is a purchase transaction that occurred after the crisis. The variable *spans beginning of crisis* is equal to one for transaction pairs when the first transaction is a buy transaction that occurred prior to the crisis and the second transaction is a sell that occurred during the crisis. *Constrained indicator* is equal to one for transactions associated with insurance companies that experienced negative operating cash flow in the year prior to the transaction and the credit rating of the RMBS had been downgraded. *Downgraded bond indicator* is equal to one for RMBS that had been downgraded. We measure RMBS fundamentals as the change in the collateral attributes from the prior transaction to the current transaction. Mortgage attributes include one-month lagged *default rates*, *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*. *Months from prior trade* measures the number of months between the first and second trade. *Five-year T-bond rate* measures the level of the 5-year T-bond at the time of the second transaction in a transaction pair. The model includes firm fixed effects. Standard errors are clustered by bond cusip. Results are robust to clustering by month of transaction, or by both cusip and month of transaction

	Dependent Variable: % Change in Price from Prior Transaction			
	Sample: 2006 - 2012			
	(1)	(2)	(3)	(4)
Spans End of Crisis Indicator * Constrained Transaction Indicator				0.233***
				(2.871)
Constrained Transaction Indicator			-0.254***	-0.254***
			(-6.952)	(-6.948)
Spans End of Crisis Indicator	0.144***	0.197***	0.195***	0.190***
	(5.754)	(8.129)	(8.100)	(7.770)
Spans Beginning of Crisis Indicator	-0.174***	-0.121***	-0.103***	-0.103***
	(-11.168)	(-9.778)	(-8.401)	(-8.406)
Downgraded Bond Indicator		-0.122***	-0.107***	-0.107***
		(-11.466)	(-9.961)	(-9.960)
Change in Collateral Quality from Prior Trade:				
Chg. Default Rate month t-1		-0.273***	-0.274***	-0.274***
		(-5.231)	(-5.319)	(-5.312)
Chg. FICO Score		0.001	0.002	0.002
		(1.323)	(1.494)	(1.501)
Chg. Combined Loan-to-Value Ratio		-0.003	-0.003	-0.003
		(-0.723)	(-0.587)	(-0.580)
Chg. Percentage of A.R.M.'s		0.110	0.105	0.105
		(1.547)	(1.499)	(1.497)
Chg. Percent of Loans Owner Occupied		-0.143	-0.194	-0.207
		(-0.702)	(-0.956)	(-1.021)
Chg. Percent of Loans No Doc./Low Doc.		0.461***	0.379**	0.375**
		(2.920)	(2.444)	(2.422)
Chg. Percent of Refinance Loans		0.273*	0.267*	0.266*
		(1.673)	(1.661)	(1.653)
Chg. Geographic Herfindahl Index		-0.368**	-0.362**	-0.363**
		(-2.278)	(-2.280)	(-2.286)
Months from Prior Trade		0.003*	0.003*	0.003*
		(1.823)	(1.873)	(1.866)
5-Year T-Bond Rate		-0.003***	-0.003***	-0.003***
		(-15.731)	(-16.279)	(-16.296)
Constant	-0.064***	0.006	0.006	0.007
	(-33.383)	(0.955)	(0.999)	(1.007)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Cluster Standard Errors by Bond	Yes	Yes	Yes	Yes
Observations	14,261	14,261	14,261	14,261
Adj. R2	0.167	0.330	0.336	0.337

Table 7. 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	28,544	28,544	28,544	28,544
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 considered NAIC level 1 and are charged a net factor of 0.004. Bonds rated BBB considered NAIC level 2 and are assigned a net factor of 0.013, BB-rated bonds, NAIC level 3, are charged 0.046, B-rated bonds, NAIC level 4, are charged 0.10, CCC-rated bonds, NAIC level 5, are charged 0.23, and bonds at or near default are considered NAIC level 6 and 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.