Liquidity Provision, Credit Risk and the Bond Spread: New Evidence from the Mortgage Market*

Xudong An
Federal Reserve Bank of Philadelphia
xudong.an@phil.frb.org

Timothy J. Riddiough
University of Wisconsin – Madison
timothy.riddiough@wisc.edu

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ABSTRACT

We study the determinants of the mortgage spread, with a particular focus on funding liquidity and default-liquidity interaction effects. Using subprime and Alt-A mortgage and securities data, we find that sector-level as well as macro funding liquidity provision affected loan rates, explaining a significant portion of the variation in spreads. Liquidity conditions just prior to loan default mattered, indicating destabilizing liquidity-driven default effects. Positive default-liquidity feedback (spiraling) effects are also documented.

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1. Introduction

A vast literature has developed in the past forty years that studies how the yield spread of defaultable bonds is determined by their credit risk (see, e.g., Merton, 1974; Jones, Mason and Rosenfeld, 1984; Titman and Torous, 1989; Collin-Dufresne, Goldstein and Martin, 2001; among many others). Largely motivated by the fact that credit risk can only explain a limited portion of the total corporate bond yield spread, a second generation of literature has stressed the role of liquidity as an important additional bond pricing factor (see, e.g., Driessen, 2005; Longstaff, Mithal, and Neis, 2005; Ericsson and Renault, 2006; Chen, Lesmond, and Wei, 2007; Dick-Nielsen, Feldhütter, and Lando; 2012; Friewald, Jankowitsch and Subrahmanyam, 2012). Bao, Pan and Wang (2011) quantify the relative importance of illiquidity and credit risk in explaining corporate bond spread, finding that, for higher-rated corporate bonds, the liquidity risk component of the spread exceeds the credit risk component. Longstaff, Mithal, and Neis (2005) come to similar conclusions.

More recently a third and fourth generation of literature has emerged that attempts to further explain the wide spreads observed in corporate bond markets. The third generation of literature begins with Chen, Collin-Dufresne and Goldstein (2009) and Chen (2010), who isolate how business cycles and rational expectations produce a credit risk premium that is tied to the marginal utility of consumption when there is the clustering of bond defaults in bad states of the economy.[1] This credit risk component in their model is distinct from the more standard effect, which more or less follows from an actuarial calculation of the current price of default risk. A fourth generation of literature is tied to the recent work of He and Milbradt (2014) and Chen et al (2014). In their models, default and liquidity risks interact to produce liquidity-driven default as well as default-driven liquidity risk components, along with the possibility of positive feedback between the two effects.

Pure credit and liquidity effects have been examined empirically using corporate and municipal bond data, but independent empirical work on the two more recent generations of literature has yet to emerge. The mortgage market provides a natural setting to undertake this type of exercise. From 2000 to 2006 funding liquidity in the non-agency (private-label) mortgage market was plentiful. Subprime and Alt-A mortgage loans were easily saleable into a secondary market where they were used to

[1] Also see Bharma, Kuehn and Strebulaev (2010) and Huang and Huang (2012) who have similar focuses.

collateralize higher-rated asset-based securities (ABS) and residential mortgage-backed securities (RMBS) that were in great demand at the time.[2] Then, as the housing market peaked in 2006 and began to bust, with loan delinquencies starting to increase, volatility in private-label ABS/RMBS prices spiked and liquidity began to recede from the market. Without liquidity in the secondary market lenders slowed their loan originations, which then created further problems for distressed homeowners who no longer had a ready source of debt financing. Meanwhile, the inability of other (liquidity-constrained) households to obtain financing sidelined an entire market of potential homebuyers to further depress house prices, especially in subprime neighborhoods.[3] As a consequence of these dynamics, along with certain other contributing factors, large waves of mortgage default happened during and after the crisis period.

The significant variation in credit risk and liquidity provision over the cycle allows us a unique opportunity to analyze how and why these effects played a role in loan pricing and credit performance. In this paper, using unique data from the non-agency mortgage market, we provide new evidence regarding the importance of liquidity—particularly *funding* liquidity—in determining the defaultable loan spread. In doing so we pay close attention to interactions between funding liquidity and credit risks, documenting how poor credit performance affected liquidity in the mortgage market, and vice versa, thus providing evidence of spiraling as funding liquidity and credit risks fed back on one another.

We develop three measures of funding liquidity. First, we follow the literature by using a specific component of the LIBOR swap spread (the Treasury convenience yield as referred to in Feldhutter and Lando (2008)) as a measure of macro, bank-sector related funding liquidity. Second, at the sector-level we introduce a new measure that we believe accurately captures funding liquidity provision for non-agency mortgage loans that were originated and sold into the secondary market: ABS/RMBS *issuance* volume normalized by subprime/Alt-A loan *origination* volume in the prior year. Finally, we compare credit risk characteristics of individual mortgage loans with the prevailing mortgage loan characteristics that are sold to the secondary market to define loan-level funding liquidity—the idea being that more a popular products as defined by their credit risk characteristics are more liquid.

[2] The size of the subprime mortgage market expanded rapidly during this time period, going from approximately $65 billion in 1995 to $1.3 trillion in 2007. During the same period, the total (prime and subprime) mortgage debt outstanding for residential properties grew from $3.3 trillion in 1995 to $11.2 trillion in 2007, surpassing the corporate bond and municipal bond markets to be the largest debt market in the U.S.

[3] For additional details and support for this described chain of events, see Mian and Sufi (2009, 2014).

We find that the mortgage spread is sensitive to all three measures of funding liquidity. In aggregate, the macro and sector-level funding liquidity measures alone explain about 40 percent of the time variation in average mortgage spread. Then, after introducing a battery of loan level credit risk controls, in the cross-section macro and sector-level funding liquidity alone still explains over 22 percent of the variation in mortgage loan spread. Loan-level funding liquidity also explains a significant amount of variation in mortgage loan spread. With a subprime and Alt-A mortgage spread range of 535 and 456 basis points, respectively, over our sample period, we estimate a lower bound of 14-18 percent of the spread being attributable to funding liquidity risk.

Our data provide loan performance history, including mortgage default realizations. This allows us the opportunity to analyze credit performance relative to market conditions and relevant risk factors at the time of default, just prior to default, and as of the loan issuance date.

Our most novel findings pertain to the interactions between liquidity and credit risks. After controlling for credit risk measured by either the credit risk component of mortgage spread or numerous borrower and loan credit risk factors, we document that borrower liquidity risk is an important determinant of credit performance. That is, we identify a particular form of liquidity-driven default. We further find that deteriorated funding liquidity conditions were destabilizing, increasing the hazard rate of default, which shows the existence of an alternative liquidity-driven default channel. In a related manner we document that, from 2008 on, sector-level funding illiquidity had greater negative effects on credit outcomes of jumbo-size loans as compared to loans qualified for purchase in the agency mortgage market.

On the issue of spiraling, we document that from 2006 through 2008—a critical period when the housing market topped out and started deteriorating, causing a reevaluation of investment performance forecasts—there is a tight relation between sector funding liquidity and mortgage default. In particular, the lagged mortgage delinquency rate is highly predictive of and negatively related to current ABS/RMBS issuance volume, suggesting a pro-cyclical default-driven liquidity effect. These results, together with the aforementioned liquidity-driven default results, depict a default-liquidity spiral occurring during the onset of the financial crisis: Increased mortgage default caused private-label ABS/RMBS investors to retreat from the secondary mortgage market, which in turn caused funding illiquidity in the primary mortgage loan origination channel. Funding illiquidity in this market then negatively affected borrowers' ability to refinance and sell their houses, thus worsening the credit performance of mortgage loans, and so on.

Our empirical findings contribute to the bond and mortgage pricing literature in several important ways. Increasing numbers of studies have found liquidity to be an important determinant of the defaultable bond spread, but the evidence is almost exclusively from the corporate bond market. We are the first to provide evidence from an important but distinct market—the housing mortgage market. Our loan-level data are highly granular, allowing us to control for numerous and potentially subtle risk effects. Further, mortgage contracts tend to be highly standardized, where we also focus our analysis on one relatively simple and pervasive loan type: the long-term fixed rate mortgage.[4] All together the richness of our data leads to rather clean identification of bond pricing factors.

It is also worth emphasizing that all loans in our sample were sold into the secondary market, which experienced substantial variation in liquidity provision during our study period. We are therefore able to construct a novel volume-based direct measure of sector-level funding liquidity. This compares to previous studies that focus on the credit component of the bond spread and attribute the unexplained portion of the spread to illiquidity or that develop indirect, often relatively complex measures of liquidity that can be a mix of asset market liquidity, funding liquidity and borrower liquidity effects. In addition, we undertake a careful matching of loan prices at issuance with credit performance outcomes, something that has been largely missing in this literature. Finally, as just alluded to, we are careful to distinguish between various types of liquidity, focusing most of our attention on the effects of funding liquidity provision.

The current study also advances the mortgage pricing literature. In the past decades, despite the introduction of many new mortgage products and the rapid growth in securitization, along with subsequent dramatic concurrent variation in funding liquidity and credit risks, the theoretical mortgage pricing literature has largely remained stuck in its initial form of applying the frictionless contingent-claims model (Kau, et al, 1987; Schwartz and Torous, 1989; Titman and Torous, 1989; Childs, Ott and Riddiough, 1996). Our results suggest that new approaches deserve consideration.[5]

The rest of the paper is organized as follows. In the next section we discuss salient features of non-agency mortgage lending and securitization as well as distinguish between various types of liquidity in order to set the stage for our subsequent analysis. In section three we describe our data sources and

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[4] In contrast, corporate bonds tend to utilize heterogeneous contract clauses and covenants that introduce variation that is difficult to categorize and control for.

[5] Recent papers such as Gan and Riddiough (2008), Downing, Jaffee and Wallace (2009) and An, Deng and Gabriel (2011) study how information asymmetry in the mortgage market affects mortgage and mortgage-backed securities pricing.

characterize the data. In section four we assess the time series and cross-sectional determinants of the mortgage loan spread, focusing on time-varying sector-level and macro funding liquidity effects. Then in section five we highlight the determinants of credit performance, with an emphasis on analyzing credit-liquidity interaction effects and spiraling. Concluding remarks can be found in a final section.

2. Preliminaries

2.1. Non-Agency Mortgage Loan Origination, Loan Pricing, and Securitization

Subprime and Alt-A loans in our data were identified as such by the originating lender, creating the basis for our sample. These mortgage loans are considered to be of lower credit quality than prime quality loans that are eligible for purchase by Fannie Mae and Freddie Mac (thus non-agency loans). The subprime and Alt-A loan designation is generally the result of the effects of one or more of the following credit risk factors: the borrower's credit worthiness, leverage and debt-to-income metrics, verification criteria (e.g., no income/asset verification), and sometimes other factors such as loan type (e.g., option-ARM).

Subprime and Alt-A loan rates at the time of origination are "risk-based," varying as a function of the aforementioned credit risk factors. Prepayment risk will also be priced depending on market conditions as well as borrower and loan contract characteristics.[6] In this study we are primarily interested in understanding the effects of liquidity risks—separately as well as how they interact with credit risks—on loan rates at origination as well as on subsequent credit performance. With our focus on time-varying liquidity risk it is imperative, however, to adequately control for loan-level credit and prepayment risks, as these risks can vary over time and correlate with the primary variables of interest.

The subprime mortgage loans we analyze were sold into the secondary mortgage market to be used as collateral for ABS that are usually traded at the home equity desk, while the Alt-A mortgage loans were collateral for private-label MBS traded at the RMBS desk. The development of a secondary market for subprime and Alt-A mortgage loans greatly enhanced liquidity in the origination market. Appendix Figure 1 shows subprime and Alt-A mortgage loan origination and securitization volume. Visual inspection shows a clear strong relation between ABS/RMBS issuance and subprime/Alt-A mortgage origination volume. Note also that securitization is seen to accelerate starting in 2002-2003 and peaked in 2005-2006. Then, as the housing market peaked in 2006 and mortgage default rates

[6] As we will show later in the paper, many subprime and Alt-A mortgage loans carry prepayment penalties that limit prepayment risk.

subsequently spiked, leading to significant volatility and then sharp declines in ABS/RMBS prices, secondary market liquidity dried up as investors lost their appetite for these securities. Without secondary market liquidity the primary channel for subprime and Alt-A loan origination also dried up.

Loans originated for distribution into the secondary market generally incurred a lag of one to three months prior to being sold into a security pool. Because of the lag most loans were originated on a forward basis, with a guaranteed purchase price (indicated by the stated mortgage loan rate). With a known forward rate, loan originators offered contract rates to borrowers so that the mortgages priced at or nearly at par for sale into the secondary market. Because we want mortgage loan rates at origination to reliably measure the mortgage loan's true price, for this study we consider only 30-year fixed rate mortgage loans.[7]

To illustrate how risk-based pricing occurred in this loan origination market, Appendix Table 1 shows a sample risk-based pricing menu of forward contract rates for 30-year fixed rate subprime mortgages. Borrowers with lower FICO credit scores pay higher interest rates, while borrowers with a lower ratio of total debt-to-income (the backend ratio) pay lower interest rates. Other factors including loan-to-value (LTV) ratio, documentation type and property type are seen to affect mortgage pricing at origination.[8]

2.2. The Various Kinds of Liquidity Provision and Liquidity Risks

In this study we focus on the role of liquidity and liquidity-credit interaction effects on the at-issue pricing and subsequent credit performance of a particular type of "bond" – the mortgage loan. While mortgage credit risks are generally thought to be well defined and understood, at least as related to the effects of leverage on the borrower's option to default, mortgage loan liquidity risks have received more limited attention. The purpose of this subsection is, by relying on the seminal work of Shleifer and Vishny (1992), Brunnermeier and Pedersen (2009), Holmstrom and Tirole (2010) and Chen et al.

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[7] Subprime and Alt-A mortgage lenders covered their origination costs by charging the borrower fees and possibly points that were paid at the time of loan origination. Fees and points in the subprime and Alt-A market during our sample period were known to vary based on high costs of loan origination as well as bilateral negotiations between borrower and lender. Loan rates were generally unaffected by these negotiations (see, e.g., White (2004, p.514)).

[8] The pricing factors we consider in this paper are more comprehensive than those displayed in this table, and the cutoffs we use do not always exactly match the pricing factors shown here. Cutoffs vary because different lenders typically used slightly different variables and cut-offs to establish pricing sheets. For example, FICO score categories shown in the table (600 and up, 575-599, 550-574) differ from the cut-offs we use. The same is true for LTV. In this scorecard the "back-end" ratio is used, which considers all debt obligations relative to income. In our case we use the "front-end" ratio, which is mortgage payments plus property taxes and property insurance relative to income. The two ratios are usually highly correlated.

(2014), among many others, to highlight the various types of liquidity provision and liquidity risks that are relevant to our analyses.

Following the recent corporate bond pricing literature, we are particularly interested in the role that macro and sector-level liquidity provision may play in loan pricing and credit outcomes. As such, using the terminology of Holmstrom and Tirole (2010), they can be labelled *outside liquidity*. Furthermore, given our focus on the use of debt (the mortgage) to fund investment and consumption (in and from owning a house), the outside liquidity of interest can, following Brunnermeier and Pedersen (2009), be called *funding liquidity*. For our purposes, *macro funding liquidity* is measured at the general banking system level and *sector-level funding liquidity* is specific to the lending sector (e.g., the subprime segment of the mortgage market). In addition, *loan-level funding liquidity* is specific to the credit characteristics of the class of mortgage instrument taken by the borrower (e.g., a mortgage loan with a higher LTV and lower FICO score will, on a relative basis, be less liquid in terms of its marketability into the secondary market than a loan with a lower LTV and higher FICO score). We will be more precise in the next section as to our exact empirical measures of macro, sector-level and loan-level funding liquidity.[9]

The borrower's own liquidity position may affect credit performance. Borrower liquidity corresponds with *inside liquidity* as defined by Holmstrom and Tirole (2010). This type of liquidity has been studied in the mortgage literature under the headings of trigger events, sub-optimal default and liquidity default, where income disruptions and financial constraints can produce liquidity-based credit outcomes that would not otherwise occur in a world without financial and asset market frictions. In this paper we will develop some new measures of borrower-specific liquidity and consider their effects in our analysis of credit performance.

Finally, Brunnermeier and Pedersen (2009) note that liquidity can have *destabilizing effects* as they interact with other factors, particularly credit risks. In recent bond pricing literature, Chen et al. (2014) analyze what they refer to as *liquidity-driven default* and *default-driven liquidity* interaction effects. Liquidity-driven default will generally be destabilitizing, since procyclical liquidity provision will exacerbate default outcomes. Default-driven liquidity is also destabilizing, particularly as it relates to

[9] Brunnermeier and Pedersen (2009) further distinguish *asset market liquidity* from funding liquidity, where, for our purposes, the distinction is between the asset and liability sides of the borrower's household balance sheet. We will not conduct a detailed analysis asset market liquidity in this study, but we will be careful to account for asset market liquidity effects on the loan's credit performance.

spiraling, when procyclical liquidity provision intensifies default outcomes which in turn results in further reductions in liquidity.

In summary, the primary emphasis in this study is on how time-varying macro and sector-level funding liquidity provision affects the mortgage loan spread at origination and subsequent credit performance. Empirical analyses of interactions between liquidity and credit risks receive particular attention. In the course of our analyses we also be mindful of other types of liquidity effects, particularly those which are loan- and borrower-specific.

3. Data Description

The primary dataset used in this paper is from Black Box Logic. This firm acts as a data aggregator that collects information from mortgage servicing companies in the U.S., which it subsequently cleans and standardizes. The raw data include approximately 22 million non-agency (jumbo, Alt-A, and subprime) mortgage loans that were sold into the secondary market to collateralize private-label RMBS/ABS.

We specifically rely on two data files from our primary dataset: the loan origination file and the loan performance file. The loan origination file provides detailed information on borrower and loan characteristics at loan origination. These data include, among other things, the borrower's FICO score, origination loan balance, loan interest rate, loan term, loan type (fixed-rate, 5/1 ARM, etc.), and loan purpose (home purchase, rate/term refinance, cash out refinance). It also includes housing collateral location information such as the zip-code and MSA. The loan performance file, which includes over 700 million monthly post-origination loan records, tracks the status of each loan at a particular point in time (e.g., current, delinquent, prepaid), as well as contains information on the current loan balance, current monthly payment, and losses (if any).

The sample period covers the years 2000 to 2008 for analyses of loan spreads at origination. Mortgage loan performance is tracked from the time of origination through loan termination or the end of the loan performance sample period, whichever comes first. In our study we specifically focus on credit performance, using a hazard model to assess the likelihood of mortgage default conditioning on the loan being current in the prior period. Loan performance is tracked through 2013.

Because credit risk in mortgage lending has been shown to depend on many different borrower characteristics, we augment our main loan data by matching the loan origination file to those in the Home Mortgage Disclosure Act (HMDA) loan application database. HMDA data provide additional borrower information including borrower race and gender.[10]

We further merge the loan-level information with MSA-level Home Price Index data from S&P/Case-Shiller, zip code-level Case-Shiller Home Price Index data from CoreLogic, and MSA-level unemployment rate data from Bureau of Labor Statistics. Current house price information is compared to the current mortgage loan balance to measure default incentives as related to the borrower's net equity (solvency) position in the house. Estimated house prices are based on recent repeat sales transactions, so they also reflect asset market liquidity conditions. MSA-level unemployment rates and loan modification rates are used together with initial payment-to-income ratios to assess the relation between borrower liquidity and credit performance.

We consider only first-lien 30-year fixed-rate (FRM), fully amortizing subprime and Alt-A mortgage loans originated in 10 large U.S. metropolitan statistical areas (MSA's).[11] These MSA's are New York, Los Angeles, Chicago, Dallas, Miami, Detroit, Atlanta, Boston, Las Vegas and Washington DC.[12] Our focus on a narrow range of loan types allows us to write down an empirical loan pricing model that is less prone to specification error and that allows for the better development of credit and liquidity risk measures. We further limit our analysis to the major MSAs to ensure we have reliable measures of house price changes, as house prices are a critical input to assessing the borrower's solvency position as it affects credit outcomes.

As discussed in greater detail below, we will use ABS/RMBS issuance volume to gauge sector-level funding liquidity of subprime and Alt-A mortgage loan originations. We normalize the ABS/RMBS issuance volume by prior year's loan origination volume to account for cross year variation in loans available for sale. ABS/RMBS issuance data are calculated based on deal-level data from Intex. Intex provides monthly ABS/RMBS issuance and performance information, and is the most comprehensive

[10] There is no unique common identifier between the two databases. We thus use variables that the loans have in common across the two datasets to conduct the match, with a success ratio of about 75 percent.

[11] Jumbo loans are excluded for much of our analysis, as these loans are typically of prime mortgage credit quality. However, later in the paper when we focus on default-liquidity interaction effects, we compare the jumbo mortgage market with the more liquid agency mortgage and MBS market.

[12] A series of filters are also applied. In particular we exclude loans originated before 2000, loans that do not fully amortize in every period, loans with missing or incorrect information including the loan origination date, original loan balance, property type, refinance indicator, occupancy status, FICO score, loan-to-value ratio (LTV), documentation level and mortgage note rate.

data source available on structured finance. Mortgage origination volume data is from Inside Mortgage Finance.

Following Feldhutter and Lando (2008), we use the Treasury convenience yield component of the LIBOR interest rate swap spread (the difference between the LIBOR swap rate and comparable maturity Treasury yield) to measure macro liquidity funding provision. Changes in the LIBOR spread are primarily the result of changes in counterparty credit risks of the panel member banks that set the LIBOR rates as well as changes in liquidity risks across the banking system. Feldhutter and Lando (2008) decompose the LIBOR spread into three components: a convenience yield from holding Treasuries (a liquidity factor), a credit risk component from the underlying LIBOR rate, and a swap market-specific factor. Based on their decomposition methodology, we take the Feldhutter and Lando (2008) Treasury convenience yield component of swap spread that is updated to 2008.[13] Because of the longer stated maturity of the fixed rate subprime and Alt-A mortgage loans used in our analysis, we focus on the 10-year swap spread.

To further aid in distinguishing between liquidity funding and credit risks, we include in our specifications the corporate bond spread (Baa minus Aaa corporate bond yield) as a measure of macro credit risks. At the sector level we considered the subprime ABX and CDS indices to provide a measure of credit risks. But unfortunately those data are only available starting in 2006. Instead we rely on the aggregate mortgage delinquency rate from the Mortgage Bankers Association (MBA). The MBA's quarterly delinquency survey provides separate treatment of fixed-rate (FRM) vs. adjustable-rate mortgages (ARM) and subprime vs. prime loans, allowing us to specifically identify the 60-day delinquency rate of suprime and Alt-A FRMs.[14]

We also incorporate the VIX as a measure of macro market risks into some of our analyses. The relevance of the VIX for bond prices is discussed in Bao, Pan and Wang (2011). Other macroeconomic variables such as the change in 10-year Treasury bond rate and the slope of the yield curve are included to control for factors that are thought to effect prepayment likelihoods and bond prices more generally.

Our final sample contains 160,133 30-year FRMs that are classified by the lender as "subprime" and "Alt-A". About half of the sample are subprime loans and the other half are Alt-A loans. Appendix

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[13] We thank Feldhutter for providing us their bond spread decomposition data, which has been updated from Feldhutter and Lando (2008) to include estimates through 2008.

[14] In MBA's delinquency survey, Alt-A is included in the prime category.

Tables 2 and 3 contains more summary statistics of our sample. For example, over 80 percent of the loans are from the 2003-2006 vintages, consistent with the pattern we see in other studies. In the year of 2008, with the shutdown of the private-label securitization market, we only observe 12 loans in our sample. The 30-year FRM loans in our 10 MSA sample are generally proportionate to the size of each MSA, even though Los Angeles and Miami are over-represented. Altogether the 10 MSAs used in this study comprise almost 25 percent of the national market.

Panel A of Table 1 displays summary statistics of the mortgage interest rate in our loan sample. The average rate over the subprime and Alt-A sub-samples are 7.66 percent and 7.02 percent, respectively. They are well above the average note rate on 30-year prime FRMs of about 6.47 percent during our study period.[15] Over time there is significant variation in the average note rate due to either changes in the base rate, changes in the mortgage spread, or both.

TABLE 1 HERE

Panel B of Table 1 reports summary statistics of the mortgage spread over the Treasury rate. For each loan we isolate the 10-year maturity Treasury rate to be used as a baseline at the time of origination, and then calculate the difference between the mortgage note rate and 10-year maturity Treasury rate. This difference is defined as the mortgage loan spread. Over the entire sample period the average spread is 349 bps for subprime loans and 271 bps for Alt-A loans. Large time variation in the mortgage spread is seen in the data. The spread sees a general decline from 2001 to 2004, with mortgage spreads beginning to gap out in 2005 and with large year-over-year increases in 2006, 2007 and 2008.

4. Funding Liquidity and the Mortgage Spread

4.1. Macro, Sector-Level and Loan-Level Funding Liquidity Measures

We follow the existing bond pricing literature by distinguishing between sector-specific and macro liquidity provision as they might affect the bond spread (see, e.g., Bao, Pan and Wang, 2011). This literature has provided alternative measures for estimating sector-specific liquidity, where the bond's bid-ask spread is the most commonly utilized metric. But utilizing the bid-ask spread requires exchange-based secondary market trades of analyzed bonds, which does not fit our data. Instead, we focus on a quantity-based measure of sector-specific liquidity: the new issuance of subprime ABS and

[15] Freddie Mac mortgage interest rate survey.

Alt-A RMBS, normalized by the subprime and Alt-A origination volume, respectively, in the prior year. The idea behind this measure is that greater issuance volume implies a stronger investor appetite for securities backed by subprime/Alt-A mortgage loans, implying it is easier for the mortgage loans be sold into the secondary market. It is important to stress that private-label securitization created a secondary market for subprime and Alt-A mortgage loans, and therefore liquidity to fund borrowers that would not be eligible to borrow in the agency mortgage market. The normalization is to account for cross-year variations in the volume of loans available for security issuers' purchase.

In Figure 1, we plot the normalized annual subprime ABS/Alt-A RMBS issuance and average subprime/Alt-A loan spread on the same chart. Visual inspection suggests a clear inverse relation between our sector-level liquidity measure – the normalized security issuance, and the mortgage spread in both the subprime and the Alt-A markets.

FIGURE 1 HERE

As noted earlier, we utilize Feldhutter and Lando's (2008) decomposed Treasury convenience yield as our primary macro liquidity risk measure. As such, it provides a measure of broad-based bank funding liquidity, where a higher Treasury convenience yield implies a reduction in macro funding liquidity provision. We plot both the Treasury convenience yield component and the swap credit risk component of the swap spread in Figure 2. On the same chart we plot the monthly time series of our sector-level funding liquidity measure – the normalized subprime ABS/Alt-A RMBS issuance. Notice that the time-series pattern of the Treasury convenience yield is very different from the subprime ABS and Alt-A MBS issuance time-series, suggesting that it help distinguish macro from sector-level funding liquidity.

FIGURE 2 HERE

At the loan-level, we compare the credit characteristics of a particular mortgage loan (the 30-year FRM) with those that are sold into the ABS/RMBS security pools. The idea here is that a riskier loan generally is less marketable in terms of selling into the secondary securitization mortgage market. Therefore, we first analyze the ABS/RMBS security pools and identify the key credit risk characteristics associated with FRM's included in the mortgage loan pools in each month. We focus specifically on the FICO and LTV as the key credit risk characteristics of a fixed-rate mortgage instrument. In doing so we create loan liquidity "buckets," using 20 point increments for FICO and 10% increments for LTV. The share of securitized loans in each FICO/LTV bucket in each month provides an aggregate measure of loan level liquidity as defined by the realized marketability of the loans. We then assign the share of the FICO/LTV bucket to each individual loan that has a matching FICO/LTV to the bucket as our loan-level funding liquidity measure. For example, assuming that 660-680 FICO score loans are a prevailing product that were bought and securitized by security issuers and that they constitute 35 percent of the securitized loans, we would then use the 35 percent as a popularity (liquidity) measure to all loans with a FICO score between 660 and 680.

4.2. Funding Liquidity as a Determinant of the Aggregate Mortgage Spread

To begin to explore the connection between funding liquidity provision and mortgage pricing we first calculate the weighted average mortgage spread in each month of loan origination, and then regress the average spread on our macro and sector-level funding liquidity measures as well as the aggregate credit risk measures. The aggregate credit risk measures include the monthly corporate bond credit spread and the fixed-rate mortgage default rate with a one-quarter lag where default rates are reported on a quarterly basis. We also include change in the 10-year Treasury rate to account for prepayment risk effects. The time series of these variables are displayed in Figures 3 and 4.

FIGURES 3 AND 4 HERE

The resulting regression takes the following form:

$$r_{j,t} = \alpha + L_{j,t}\beta + Z_{j,t}\gamma + \varepsilon_{j,t}, \ t = 1, \dots T; j = 1,2 \qquad (1)$$

where $r_{j,t}$ indicates the average subprime and Alt-A mortgage spread; $L_{j,t}$ denotes macro and sector-level funding liquidity measures; $Z_{j,t}$ indicates the aggregate credit and prepayment risk factors; and $\varepsilon_{j,t}$ is the disturbance term.[16] We separate subprime from Alt-A loans (indicated by the j subscript), implying we have a panel of data.

Regression results are reported in Table 2. In model 1, we only include funding liquidity variables in the regression. Both macro and sector-level funding liquidity variables are seen to be statistically significant. A higher Treasury convenience yield, implying a reduction in macro funding liquidity provision, is associated with a higher mortgage spread, while higher ABS/RMBS issuance volume, implying greater sector-level funding liquidity, is associated with a lower mortgage spread. The adjusted-R^2 from the regression is about 40 percent.

[16] In all regression analyses to follow continuous variables have been standardized.

TABLE 2 HERE

In model 2, we only include the aggregate credit and prepayment risk measures. In this specification the sector-level credit risk variable is highly significant, where a higher lagged mortgage default rate is associated with a higher mortgage spread. The corporate bond credit spread is statistically insignificant. Aggregate prepayment risk, measured by change in the 10-year Treasury rate, is also significant with the expected sign. The adjusted-R^2 of model 2 is about 44 percent.

In model 3 we include all the aforementioned liquidity, credit and prepayment risk factors. The results are highly consistent with initial findings, with macro and sector-level funding liquidity risks as well as sector-level credit and prepayment risk all affecting the mortgage spread. The adjusted-R^2 of model 3 is about 67 percent. Finally in model 4, we include year-fixed effects. Results are highly consistent with prior specifications, where, in addition, the corporate bond spread becomes statistically significant with the expected positive sign.

As a robustness check, to address spurious time-series regression concerns, we take first-order differences in the dependent and all independent variables and run the *change* regression. Results reported in Appendix Table 2 indicate that our initial findings are robust.[17]

Next, we explore the relation between ABS/RMBS issuance volume and the LIBOR credit risk, as well as the VIX which serves as a broader measure of market risk (see, e.g., Bao, Pan and Wang, 2011). The LIBOR credit risk measure is again from Feldhutter and Lando's (2008) swap spread decomposition. Table 3 contains our regression results. Interestingly, we see that across all four specifications, ABS/RMBS issuance volume and the LIBOR credit risk have a strong negative relationship. In contrast, VIX is only significant when it is included in the model alone, becoming insignificant when it is included in the model together with the LIBOR credit risk. We interpret these results as providing some initial evidence of the existence of *default-driven liquidity*, but we will revisit this issue in more depth later in our analysis.

TABLE 3 HERE

4.3. Funding Liquidity and Loan-Level Mortgage Spread

In this section we incorporate the detailed information we have for each subprime and Alt-A mortgage loan in our sample. This allows us to control for borrower, housing collateral and loan contracting

[17] Augmented Dickey-Fuller tests indicate marginal significance with respect to the mortgage spread time series having a unit root.

variables that might correlate with our broader measures of funding liquidity risks. The additional of large sample cross-sectional variation from individual loans introduced into the regression also aids in identification.

With the introduction of these data, the mortgage spread regression takes the following form:

$$r_{i,j,t} = \alpha + L_{j,t}\beta + Z_{j,t}\gamma + X_{i,j,t}\delta + \varepsilon_{i,j,t},\ i = 1, \dots N;\ j = 1,2;\ t = 1, \dots T \qquad (2)$$

Here $r_{i,j,t}$ is the subprime/Alt-A loan spread for loan i originated at time t (the j subscript indicates whether the loan is subprime or Alt-A), $L_{j,t}$, our funding liquidity measures, $Z_{j,t}$, our aggregate credit and prepayment risk measures, $X_{i,j,t}$, a vector of loan-level credit and prepayment risk factors that we will discuss in more detail below, and $\varepsilon_{i,j,t}$ is the disturbance term. As before, time increments are monthly unless otherwise indicated.

The $X_{i,j,t}$ vector includes an exhaustive list of observable borrower, collateral and loan contracting characteristics at the time of origination that are thought to affect default and prepayment risk. These characteristics include loan size, borrower FICO score, the payment-to-income ratio, combined LTV (to account for one or more liens on a property), documentation type, loan type, property type, loan purpose, occupancy status, prepayment penalty, borrower race, and gender. We also include college education rates by residence zip code. Inclusion of these risk factors is supported by industry practice as well as by the existing literature (see, e.g., among many others, Hendershott and Shilling, 1989; Pennington-Cross, 2003; An et al, 2012).

On the supply side of the mortgage market, lenders with lower funding and/or operational costs may offer better rates to their borrowers. With this in mind we classify lenders as small, medium and large as measured by their loan production in each MSA on an annual basis. For the large lender category we identify the top one percent based on loan production.[18] Small lenders are identified as the bottom 10 percent in origination volume in a particular year in a specific MSA.

Finally, in all model specifications we control for collateral location by including MSA dummy variables. We also include vintage-fixed effects in one of our specifications. In addition, to account for potential non-linearities in prominent loan-level credit and prepayment risk factors, we allow step functions for certain variables such as FICO score and payment-to-income ratio, and use discrete

[18] Typically three or four lenders are included in this category in a specific year.

variables to indicate particular size or timing ranges for combined LTV and prepayment penalty/lockout period, respectively.

Summary statistics for the aforementioned loan-level credit and prepayment risk factors as well as lender size categories were reported in Appendix Table 3. Table 4 contains the loan-level mortgage spread regression results. In model 1, we only include our macro and sector-level funding liquidity measures. Results are consistent with those found in our previous analysis. In particular, our measure of macro funding liquidity, Felhutter and Lando's (2008) Treasury convenience yield, is positively related with mortgage spread, with ABS/RMBS issuance volume negatively related to mortgage spread, implying that increased funding liquidity provision of both macro and sector level cause the mortgage spread to compress. The adjusted-R^2 from the regression is about 22 percent.

TABLE 4 HERE

In model 2, we only include our loan-level funding liquidity measures. Results indicate that when the loan is a popular product, defined as being in the prevailing FICO and LTV buckets in the securities pools, the loan spread is smaller. Thus, in addition to macro and sector-level funding liquidity, loan-level funding liquidity is also an important component of the mortgage loan spread.

In model 3, we only include aggregate credit and prepayment risk measures in the regression. Results show that these variables are all significant (recall that the corporate bond credit spread was insignificant in the aggregate time series specification), with coefficients that all have signs and magnitudes consistent with those seen previously. In model 4, we include funding liquidity as well as aggregate credit and prepayment risk measures. Again, results are consistent with those just discussed and what we see in the aggregate regression.

In model 5, in addition to the primary variables of interest, we include all of the loan-level and supply-side variables as controls. Estimated coefficients of our control variables are not reported in the table for the sake of space, but all have the expected signs. For example, all else equal a higher FICO score reduces the mortgage spread; payment-to-income ratio and combined LTV are positively associated with mortgage spread; and low documentation loans and loans for second home or investment property result in a higher spread.

We see that including detailed control variables does not affect the signs or statistical significance of our funding liquidity or aggregate credit/prepayment risk measures. In this full model specification about 38 percent of the variation in the mortgage spread is explained.

Finally in model 6, we include vintage-fixed effect. Parameter estimates of our focus variables do not materially change but the model fit improves slightly.

Based on these empirical model estimates we can calculate the liquidity premium in the loan rate relative to the total mortgage loan spread. To do this we identify pair values in the data for our macro (Treasury convenience yield component of LIBOR swap spread) and sector-level (ABS/RMBS issuance volume) measures of liquidity provision that generate maximum and minimum values as they contribute to the loan spread. We find the paired range to be 98 basis points for subprime loans and 65 basis points for Alt-A loans. Given that the range of the total mortgage spread is 535 basis points for subprime loans and 456 basis points for Alt-A loans, these magnitudes imply that, as a conservative estimate, the liquidity premium contributes approximately 14-18 percent (98÷535=0.18 and 65÷456=0.14) to the total variation in the loan spread. These estimates are near the liquidity premium estimate of 14 percent in Friewald, Jankowitsch and Subrahmanyam (2012) for higher credit risk corporate bonds.

5. Liquidity Provision, Credit Risk, Interaction Effects and Credit Performance

Our mortgage data allow us to observe the post-origination credit performance of previously originated loans. This means that we can follow each loan from the time of its origination through termination—with a focus on mortgage default as a credit-driven loan termination outcome. This contrasts with empirical studies of the corporate bond spread that typically rely on secondary market trades of non-distressed debt with spreads measured as of particular points in time. Our data therefore allow us to examine the predictive power of certain components of the loan spread as related to realized credit performance, as well as to consider contemporaneous (post-origination) liquidity conditions and possible interactions between credit and liquidity risks. To our knowledge, as applied to analyzing the determinants of bond prices and credit performance, liquidity-credit interaction effects have yet to be independently empirically tested.

The credit performance model we estimate is a standard Cox proportional hazard model for default probability, with the following form. Conditional on a loan being current (not prepaid or having gone to term, and performing) $T-1$ periods after origination, the hazard rate of default of a mortgage loan at period T is:

$$h_i(T;Z_{i,t}) = h_0(T)\exp(Z_{i,t}'\beta), i = 1,\cdots n. \quad (3)$$

Here $h_0(T)$ is the baseline hazard function, which only depends on the age (duration) of the loan. It is an arbitrary function that allows for a flexible default pattern over time.[19] Covariates are indicated by $Z_{i,t}$, which can be static or time varying, and which result in proportional shifts in the hazard rate without otherwise affecting the duration pattern of default. For our purposes a default (non-performance) event is defined as over 60 day's delinquent.

A key credit risk variable documented in the literature is negative equity. Negative equity is defined as the percentage by which the market value of the mortgage (using current interest rates) exceeds the market value of the house (using the local Case-Shiller home price index). We further adjust it by MSA house price return volatility following An, Deng and Gabriel (2015). This is meant to provide an option-based measure of the net equity position of the borrower when liability is limited to the housing collateral. A larger value indicates a greater incentive for rational default, where the literature has found consistent support for the existence of rational option-based default incentives (see, e.g., Deng, Quigley and Van Order, 2000 and An, Deng and Gabriel, 2015). To capture potential non-linearities, we also include the square term of negative equity.

Borrower liquidity has proved to be an important determinant of mortgage default; e.g, loss of job can cause borrower-liquidity problems and hinder mortgage loan repayment (see, e.g., Foote, Gerardi, and Willen, 2008; Elul et al, 2010; Campell and Cocco, 2015). Because we do not have post-origination borrower income or employment status data, we include the average MSA-level unemployment rate to proxy for the likelihood of a negative income shock.[20]

Due to consideration of the competing risks of prepayment and default, we include a measure of refinance incentives in our model. Our refinance incentive measure is the percentage difference between the loan's estimated market value and its stated book value, representing an important control for refinance-prepayment incentives as they may affect credit outcomes. Other control variables include loan, borrower, lender, and zip code characteristics.

Loan spread should reflect lenders' *ex ante* assessment of the credit and prepayment risks, together with liquidity risk as we discuss in this paper, of a mortgage loan. We further note that an alternative

[19] Notice that the loan duration time *T* is different from the natural time t, which allows identification of the model.
[20] An, Deng and Gabriel (2015) shows that this variable serves as a good proxy of borrower income change in a hazard model.

approach to model mortgage default risk is to use loan spread as a catch-all variable that could replace negative equity, unemployment shocks, refinance incentives, and other loan and borrower variables that affect the timing of loan termination. Consequently, we use loan spread alone in one of our specifications.

An important consideration here is that the loan spread contains an illiquidity component that is separate and distinct from the other termination risk loan spread components. Therefore, we first orthogonalize loan spread to our funding liquidity measures—the Treasury convenience yield, ABS/RMBS issuance volume, and loan-specific funding liquidity measures—taking the residuals from a first-stage regression and place them (loan spread⊥) into the hazard model.

5.1. Preliminaries: Baseline Default Model and Borrower-Specific Liquidity

In Table 5, Model 1 we report our default model results where the orthogonalized loan spread and its square term are the main variables of interest included in the hazard model. We also include performance quarter dummy variables, a credit category variable indicating whether the loan is classified a subprime or Alt-A, and vintage-fixed effect. The coefficient on the loan spread term is positive and statistically significant, while that of the square term is negative and statistically significant, indicating a concave relationship between default risk and the orthogonalized loan spread.

TABLE 5 HERE

Next we introduce a battery of covariates that are meant to explain mortgage default outcomes. These covariates include all of the loan-level credit risk factors used in the mortgage spread regression, as well as the time varying-contemporaneous variables. Recall that the latter set of variables include a measure of the contemporaneous net equity position of the borrower, change in the MSA-level unemployment rate (a proxy for the borrower's own liquidity risk), and refinance incentive variable.

Estimation results are reported Table 5, model 2, with findings that generally conform with expectations. For example, negative equity and its square term are both statistically significant and positive, implying that the propensity for borrower default increases at an increasing rate as a function of negative net equity.

While equity's effect on mortgage credit performance has been well documented, borrower liquidity effects are less well understood. With this in mind, first note that the payment-to-income ratio is a direct measure of the borrower's liquidity position at the time of loan origination. Estimation results show that default hazard rates are increasingly sensitive to increases in the payment-to-income ratio, confirming previous findings of An et al. (2012), among others. Further, our proxy for borrower liquidity risk—the change in the MSA-level unemployment rate from the time of loan origination to the current date—is positive and highly significant, indicating that negative income shocks are an important contributor to credit performance.[21]

5.2. Liquidity-Driven Default

He and Milbradt (2014) and Chen et al (2014) argue that liquidity and credit risks interact to affect corporate bond prices. The basic idea is that, in addition to independent liquidity and credit risk component effects, there can be liquidity-driven default as well as default-driven liquidity effects. We have just demonstrated in section 5.2 a borrower-specific liquidity-driven default effect, and now focus on funding liquidity effects.

The basic intuition for funding liquidity-driven default follows from Shleifer and Vishny (1992) in their analysis of industry conditions and fire sales. When liquidity is limited or unavailable to (financially-constrained) industry insiders to fund the purchase and subsequent (efficient) operation of assets, defaults and associated losses increase due to further depressed asset values.

Using our mortgage data we now conduct tests to assess this hypothesized effect. The first simple test we devise is to add contemporaneous (one-quarter lagged) funding liquidity measures described previously. As sector-level liquidity is the most relevant effect based on the stated liquidity-driven default argument, we focus on ABS/RMBS issuance volume. Estimation results are shown in Table 5 under models 3 and 4.

Our sector-level funding liquidity variable is significant in both models. Illiquidity in the subprime ABS and Alt-A RMBS issuance markets cause lenders to refrain from originating new loans, which

[21] To further assess the robustness of the MSA-level unemployment rate as a proxy for borrower liquidity risks, we use our loan performance data to identify the time-varying loan modification rate at the MSA level. Loan modifications generally require extensive documentation of the borrower's deteriorated liquidity position for lender approval to occur, where events such as extended unemployment, divorce or medical hardship must be demonstrated. Consequently, the loan modification rate is a direct measure of contemporaneous local liquidity stresses experienced by mortgage borrowers. We find the correlation between the change in the MSA unemployment rate and the MSA modification rate to be strongly positive at 0.606. We also interact the payment-to-income ratio at loan origination with the change in the MSA unemployment rate, and include it in the baseline hazard model. We find the coefficient on the interaction term to be positive and significant, while the individual terms retain their signs and statistical significance. We interpret this as additional evidence as to the importance of borrower liquidity in contributing to default outcomes, as those starting with tighter income constraints (higher payment-to-income ratio) are shown to be more vulnerable to unemployment shocks and thus liquidity-driven default risks.

increases borrowers' difficulty in rolling over their debt (through refinance) or selling their properties (because of reductions in asset market liquidity) in order to pay off their loans.

To provide further evidence of funding liquidity-driven default, we examine the differential impacts of sector funding liquidity on conforming- versus jumbo-size loans. Loans that are conforming meet the size limit restrictions and therefore are eligible for purchase by Fannie and Freddie. The Non-Agency MBS market began to contract beginning in 2007, whereas Fannie and Freddie continued to fund mortgage loans through secondary market purchase throughout the sample period. Therefore, we hypothesize that funding illiquidity experienced in the Non-Agency MBS market had a stronger impact on jumbo loans than on conforming loans.

Models 3 and 4 in Table 5 are augmented to include a dummy variable to indicate whether the remaining balance of a loan in each quarter is higher than the conforming loan limit (jumbo size remaining balance), where we also interact this variable with our measure of contemporaneous sector-level funding liquidity – normalized ABS/RMBS issuance volume. With results reported in Table 6 under Models 5 and 6, we see that, after controlling for other loan-level credit factors, the effects of funding illiquidity in the mortgage sector is significantly greater for jumbo loans than for conforming loans. That is, the conforming loan market, with its smaller agency-qualified loan sizes, offered an outlet for potential refinancing of distressed loans and, perhaps more importantly, provided liquidity for potential home purchasers and thus helped support house price levels.

TABLE 6 HERE

We now turn back to Table 5 and consider one additional test. Notice that in addition to the *contemporaneous* sector-level funding liquidity measure, we also include the sector-level funding liquidity variables measured *at loan origination* to the default hazard model. The hypothesis here is that there could be a default-driven funding liquidity effect in response to a negative shock that is *anticipated* to adversely affect credit outcomes in the future. This anticipated effect would cause a reduction in funding liquidity provision at the time of loan origination to generate a marginally higher fixed loan rate. Estimatio results weakly support this hypothesis, as we show in Models 3 and 4 in Table 5.

5.3. Spiraling

He and Milbrandt (2014) and Chen et al. (2014) argue that destabilizing default-liquidity spirals can occur due to positive feedback. We have already shown a significant negative relation between contemporaneous ABS/RMBS issuance volume and the propensity for borrower default, which we take as evidence for liquidity-driven default. Now, to test for destabilizing feedback effects, with the idea being that recent default experience influences sector liquidity, we regress subprime ABS and Alt-A RMBS issuance volume on lagged mortgage delinquency rate. We separate our study period into two sub-periods: January 2000 to May 2006, and June 2006 to January 2008, where the latter is the crisis period when a large number of defaults were observed by market participants. We also separate subprime loans from Alt-A to generate separate specifications. Estimation results are reported in Table 7.

TABLE 7 HERE

Interestingly, we find no relationship between ABS/RMBS issuance volume and mortgage delinquency rate during 2000.1-2006.5. However, using data starting at the peak of the housing market and continuing through the subsequent early stages of the sharp and prolonged decline in house prices, we find the relation between delinquency rate and ABS/RMBS issuance volume to be strong. That is, ABS/RMBS issuance volume declined markedly when the delinquency rate increased, where variation in the lagged delinquency rate by itself explains a large portion of the variation in ABS/RMBS issuance volume.

We believe these results provide support for the existence of destabilizing default-driven funding liquidity effects in the mortgage market. When combined with our earlier findings of destabilizing liquidity-driven default, we provide some initial evidence of feedback effects occurring in the Non-Agency residential mortgage market. In particular, when Non-Agency ABS/MBS investors saw increasing numbers of mortgage defaults, they began to lose their appetite for investment. Illiquidity in the secondary market then caused lenders to refrain from originating new loans, which increased borrowers' difficulty in rolling over their debt (through refinance) or selling their properties in order to pay off their loan. As a result borrowers defaulted at higher rates, which then affected the ability of loan originators to sell new mortgages into securities, and so on.

6. Conclusions

A meaningful body of the finance literature has been devoted to the pricing of corporate and municipal bonds. This paper expands and contributes to that literature in several ways. First, we analyze a data set populated with non-Agency mortgage loans originated between 2000 and 2008. These data offer a large number of observations in comparison to those available in previous studies, standardized loan contracts, granular loan-level information that allows us to control for many credit risk factors, and the ability to match loan issuance and current market condition information with realized credit performance. With these data we are able to test for the effects of macro, sector-level and loan-level funding liquidity provision on loan pricing at the time of issuance as well as to assess default-liquidity interactions and feedback that affect credit performance.

We provide evidence that funding liquidity explains a significant portion of the variation in loan spreads. Specifically, we find that our measures of macro and sector-level funding liquidity explain about 40 percent of the time variation in aggregate subprime and Alt-A mortgage spread, which is similar to the estimate in Bao, Pan and Wang (2011) on corporate bonds. We also estimate a lower bound of the liquidity premium to be 14-18 percent of total non-Agency mortgage spread, which is consistent with the findings of Friewald, Jankowitsch and Subrahmanyam (2012) in their analysis of below investment-grade corporate bonds.

We further document the existence of liquidity-driven default as well as default-driven liquidity interactions. Analysis also indicates the existence of default-liquidity spiraling effects occurring during the critical 2006 to 2008 time period during which house prices peaked and turned downward. Declining house prices triggered loan defaults which then reduced liquidity in the ABS/RMBS market. This in turn reduced liquidity in the mortgage market, causing defaults to increase, resulting in further reductions in sector-level funding liquidity, and so on and so forth.

Lastly, our results have implications for both the theoretical and empirical mortgage pricing literature, which to date has not recognized the potential role that funding liquidity and default-liquidity interaction effects can play in the pricing of mortgage loans.

References

Agarwal, Sumit, Effi Benmelech, Nittai Bergman, and Amit Seru, 2012, Did the community reinvestment act (CRA) lead to risky lending? SSRN working paper.

An, Xudong, Yongheng Deng and Stuart A. Gabriel, 2011, Asymmetric information, adverse selection and the pricing of CMBS, *Journal of Financial Economics* 100(2), 304-325.

An, Xudong, Yongheng Deng and Stuart A. Gabriel, 2015, Default option exercise over the financial crisis and beyond, UCLA Ziman Center for Real Estate working paper.

An, Xudong, Yongheng Deng, Eric Rosenblatt and Vincent W. Yao, 2012, Model stability and the subprime mortgage Crisis, *Journal of Real Estate Finance and Economics* 45(3), 545-568.

Bao, Jack, Jun Pan and Jiang Wang, 2011, The illiquidity of corporate bonds, *Journal of Finance* 66(3), 911-946.

Bharma, H., L. Kuehn and I. Strebulaev, 2010, The levered equity risk premium and credit spreads: A unified framework, *Review of Financial Studies*, 23, 645-703.

Brunnermeier, Markus K. and Lasse Heje Pedersen, 2009, Market liquidity and funding liquidity, *Review of Financial Studies* 22(6), 2201-2238.

Caberello, Ricardo J. and Arvind Krishmurthy, 2006, Bubbles and capital flow volatility: Causes and risk management, *Journal of Monetary Economics* 53, 35-53.

Campbell, J.Y. and J.F. Cocco. 2015. A Model of Mortgage Default. *Journal of Finance*, 70(4): 1495-1554.

Chen, Hui, 2010, Macroeconomic conditions and the puzzles of credit spreads and capital structure, *Journal of Finance* 65, 2171-2212.

Chen, L., P. Collin-Dufresne, and R. S. Goldstein, 2009, On the relation between the credit spread puzzle and the equity premium puzzle, *Review of Financial Studies* 22, 3367-3409.

Chen, Hui, Rui Cui, Zhiguo He and Konstantin Milbradt, 2014, Quantifying liquidity and default risks of corporate bonds over the business cycle, SSRN working paper.

Chen, L., D. A. Lesmond, and J. Wei, 2007, Corporate yield spreads and bond liquidity, *Journal of Finance* 62(1), 119-149.

Cheng, Ing-haw, Sahil Raina and Wei Xiong, 2014, Wall Street and the housing bubble. *American Economic Review* 104(9), 2797-2829.

Childs, P.D., S.H. Ott, and T. J. Riddiough, 1996, The pricing of multiclass commercial mortgage-backed securities, *Journal of Financial and Quantitative Analysis* 31(4), 581-603.

Collin-Dufresne, P., R. S. Goldstein, and S. Martin, 2001, The determinants of credit spread changes, *Journal of Finance* 56(6), 2177-2207.

Demyanyk, Y., and O. Van Hemert, 2011, Understanding the subprime mortgage crisis, *Review of Financial Studies* 24(6), 1848-1880.

Deng, Yongheng, John M. Quigley, and Robert Van Order, 2000, Mortgage terminations, heterogeneity and the exercise of mortgage options. *Econometrica* 68(2), 275-308.

Dick-Nielson, Jens, Peter Feldhutter and David Lando, 2012, Corporate bond liquidity before and after the onset of the subprime crisis, *Journal of Financial Economics* 103, 471-492.

Downing, C., D. Jaffee, and N. Wallace, 2009, Is the market for mortgage-backed securities a market for lemons? *Review of Financial Studies* 22(7), 2457-2494.

Driessen, Joost, 2005, Is default event risk pricing into corporate bonds? *Review of Financial Studies* 18: 165-195.

Duffie, Darrell and Kenneth J. Singleton, 1997, An econometric model of the term structure of interest rate swap yields*, Journal of Finance* 52, 1287-1321.

Elul, Ronel, Nicholas S. Souleles, Souphala Chomsisengphet, Dennis Glennon, and Robert Hunt. 2010. What "Triggers" Mortgage Default? *American Economic Association Papers and Proceedings*, 100(2), 490-94.

Ericsson, Jan and Olivier Renault, 2006, Liquidity and credit risk, *Journal of Finance* 61, 2219-2250.

Foote, Chris, Kristopher S. Gerardi and Paul S. Willen. 2008. Negative Equity and Foreclosure: Theory and Evidence. *Journal of Urban Economics*, 64(2), 234–245.

Friewald, N., R. Jankowitsch, and M. Subrahmanyam, 2012, Illiquidity or credit deterioration: a study of liquidity in the U.S. corporate bond market during financial crises, *Journal of Financial Economics* 105(1), 18-36.

Fuster, Andreas, Laurie Goodman, David Lucca, Laurel Madar, Linsey Molloy and Paul Willen, 2013, The rising gap between primary and secondary mortgage rates, *FRBNY Economic Policy Review*, December, 17-38.

Gan, J. and T. J. Riddiough, 2008, Monopoly and information advantage in the residential mortgage market, *Review of Financial Studies* 21(6), 2677-2703.

He, Zhiguo and Konstantin Milbradt, 2014, Endogenous liquidity and defaultable bonds, *Econometrica* 82(4): 1443-1508.

Hendershott, Patric H. and James D. Shilling, 1989, The impact of agencies on conventional fixed-rate mortgage yields, *Journal of Real Estate Finance and Economics* 2, 201-115.

Holmström, Bengt and Jean Tirole, 2010, *Inside and Outside Liquidity*, MIT Press.

Hou, David and David Skeie, 2014, LIBORS: origins, economics, crisis, scandal, and reform, *Federal Reserve Bank of New York Staff Reports* No. 667.

Huang, Jingzhi and Ming Huang, 2012, How much of the corporate-Treasury yield spread is due to credit risk? *Review of Asset Pricing Studies* 2, 153-202.

Huang, Ying, Salih, Neftei and Ira Jersey, 2003, What drives swap spread? Credit or liquidity? University of Reading working paper.

Jones, E. Philip, Scott P. Mason, and Eric Rosenfeld, 1984, Contingent claims analysis of corporate capital structures: An empirical investigation, *Journal of Finance* 39(3), 611-625.

Kau, J. B., D. C. Keenan, W. J. Muller III and J. F. Epperson, 1987, The valuation and securitization of commercial and multifamily mortgages, *Journal of Banking and Finance* 11, 525-546.

Kiyotaki, Nobuhiro and John Moore, 1997, Credit cycles, Journal of Political Economy 105(2): 211-248.

Longstaff, F. A., S. Mithal, and E. Neis, 2005, Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market, *Journal of Finance* 60 (5), 2213-2253.

Merton, R. C, 1974, On the pricing of corporate debt: the risk structure of interest rates, *Journal of Finance* 29(2), 449-470.

Mian, Atif and Amir Sufi, 2009, The consequences of mortgage credit expansion: Evidence from the U.S. mortgage default crisis, *Quarterly Journal of Economics* 124 (4), 1449-1496.

Mian, Atif and Amir Sufi, 2014, *House of Debt,* University of Chicago Press: Chicago, IL USA.

Pennington-Cross, A, 2003, Credit history and the performance of prime and nonprime mortgages, *Journal of Real Estate Finance and Economics* 27 (3), 279-301.

Piskorski, Tomasz, Amit Seru, and James Witkin, 2014, Asset quality misrepresentation by financial intermediaries: Evidence from RMBS market, *Journal of Finance*, forthcoming.

Schwartz, Eduardo, S. and Walter N. Torous, 1989, Prepayment and the valuation of mortgage-backed securities, *Journal of Finance* 44(2), 375-392.

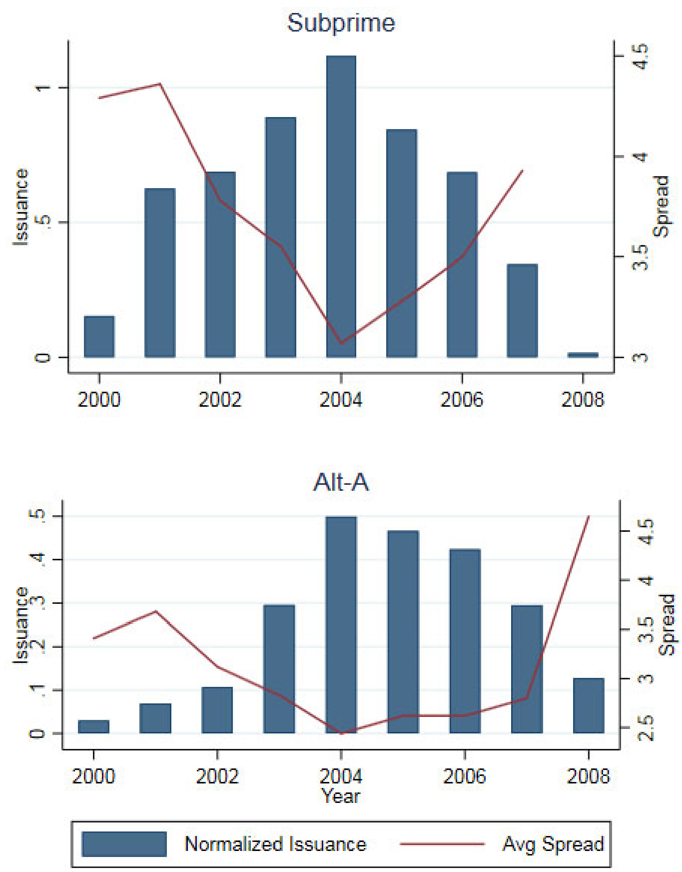
Shleifer, Andrei and Robert W. Vishny, 1992, Liquidation values and debt capacity: A market equilibrium approach, *Journal of Finance* 47, 1343-1366.

Stiglitz, J.E., Weiss, A, 1981, Credit rationing in markets with imperfect information, *American Economic Review* 71 (3), 393-410.

Titman, S., and W. N. Torous, 1989, Valuing commercial mortgages: An empirical investigation of the contingent-claims approach to pricing risky debt, *Journal of Finance* 44(2), 345-373.

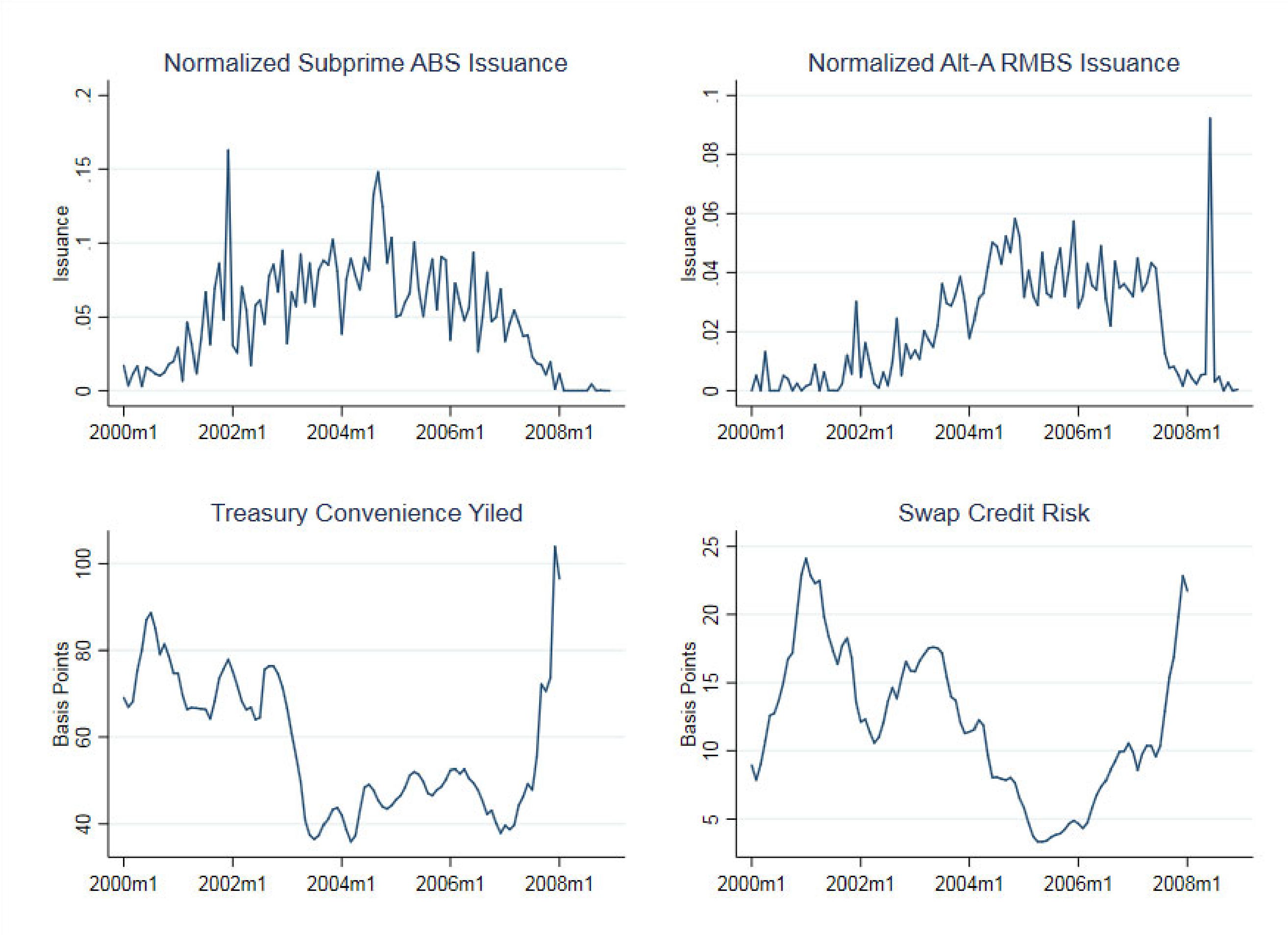
White, Alan M., 2004, Risk-based Mortgage Pricing: Present and Future, *Housing Policy Debate* 15(3), 503-531.

Figure 1 Annual Average Loan Spread and Normalized ABS/RMBS Issuance



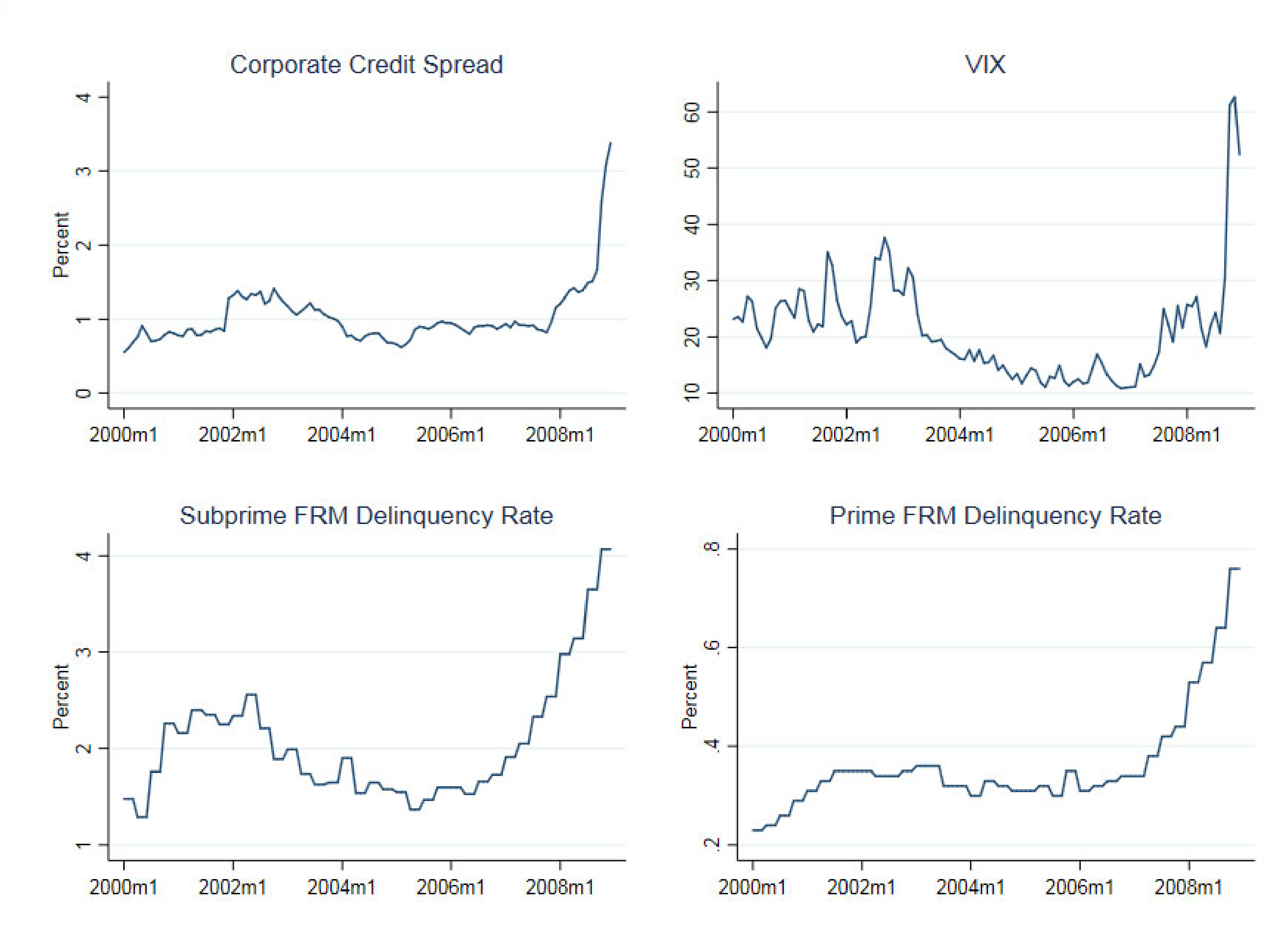
Note: the normalized ABS/RMBS issuance is based on Intex and Inside Mortgage Finance data, calculated as the subprime ABS/Alt-A RMBS issuance volume divided by prior year's subprime/Alt-A mortgage origination volume. The loan spread is calculated as the mortgage note rate minus 10-year (comparable maturity) Treasury bond rate based on the BlackBox loan-level data and Federal Reserve Board interest rate data.

Figure 2 ABS/RMBS Issuance Volume (normalized), and the Liquidity and Credit Risk Components of the Interest Rate Swap Spread



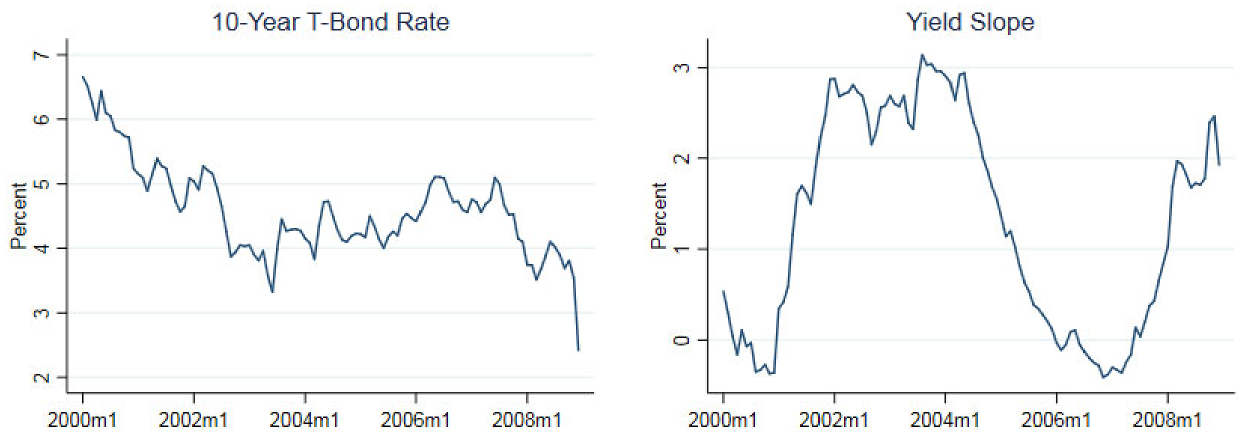
Note: the monthly subprime ABS/Alt-A RMBS issuance volume is calculated based on data from Intex and Inside Mortgage Finance, and the Treasury convenience yiled and Swap credit spread are from Feldhutter and Lando (2008).

Figure 3 Corporate Bond Spread, VIX, and Mortgage Delinquency Rate



Note: the corporate bond spread is calculated based on corporate bond yield data from the Federal Reserve Board (originally from Moody's); VIX is from the Chicago Board of Options Exchage; and the subprime and Alt-A fixed-rate mortgage delinquency rates are from the Mortgage Banks Association. The mortgage delinquency rate is at quarterly frequency, while other data is monthly.

Figure 4 Treasury Bond Rate and the Yield Curve Slope



Note: the Treasury rates are from the Federal Reserve Board and the Yield Curve slope is calculated as the 10-year Trasury bond rate minus the 3-month Treasury bill rate.

Table 1 Mortgage Interest Rate and Spread of Our Loan Sample, by Year of Origination

This table presents descriptive statistics of the note rate of the fixed-rate subprime and Alt-A mortgage loans in our sample. It also shows the descriptive statistics of the mortgage spread, which is the mortgage note rate over comparable maturity Treasury rate. The statistics are shown for each vintage.

Panel A: Mortgage Interest Rate

	Subprime						Alt-A					
	N	Mean	Std Dev	5th Pctl	Median	95th Pctl	N	Mean	Std Dev	5th Pctl	Median	95th Pctl
2000-2008	80,054	7.66	1.82	4.00	7.75	10.39	80,079	7.02	1.40	5.13	6.90	9.28
2000	1,761	10.62	1.39	8.38	10.75	12.50	1,306	9.75	1.00	8.25	9.75	11.50
2001	2,352	9.39	1.38	7.00	9.63	11.23	2,113	8.69	1.15	6.88	8.75	10.50
2002	3,278	8.53	1.39	6.50	8.50	10.74	3,969	7.95	1.08	6.38	7.88	9.75
2003	8,713	7.57	1.30	5.88	7.55	9.60	10,801	6.93	1.03	5.63	6.88	8.63
2004	11,780	7.13	1.43	4.96	7.13	9.28	11,035	6.62	1.11	5.38	6.59	8.29
2005	17,803	7.17	1.42	5.00	7.20	9.35	16,424	6.61	1.12	5.25	6.55	8.25
2006	20,291	7.82	1.97	2.54	8.00	10.38	20,528	7.12	1.46	4.00	7.20	9.13
2007	7,571	7.70	2.40	2.00	8.25	10.50	6,573	6.90	1.76	2.00	6.88	9.58
2008	-	-	-	-	-	-	6	7.15	1.03	6.42	7.15	7.88

Panel B: Mortgage Spread over the Treasury Rate

	Subprime						Alt-A					
	N	Mean	Std Dev	5th Pctl	Median	95th Pctl	N	Mean	Std Dev	5th Pctl	Median	95th Pctl
2000-2008	80,054	3.49	1.21	1.69	3.38	5.65	80,079	2.71	1.01	1.34	2.55	4.60
2000	1,806	4.29	1.27	2.04	4.40	6.11	1,317	3.41	1.02	1.92	3.40	5.25
2001	2,448	4.36	1.25	2.07	4.50	6.14	2,144	3.68	1.11	1.96	3.59	5.55
2002	3,484	3.78	1.20	1.81	3.77	5.79	4,165	3.12	1.02	1.56	3.11	4.81
2003	9,465	3.55	1.19	1.74	3.45	5.67	12,396	2.83	1.08	1.27	2.75	4.82
2004	12,996	3.07	1.18	1.31	2.97	5.24	12,405	2.44	0.99	0.97	2.34	4.24
2005	19,331	3.28	1.04	1.81	3.16	5.23	17,971	2.62	0.84	1.44	2.49	4.16
2006	22,141	3.50	1.20	1.70	3.43	5.64	22,381	2.62	0.96	1.35	2.47	4.41
2007	8,377	3.93	1.26	1.99	3.93	5.93	7,294	2.80	1.10	1.50	2.51	5.03
2008	-	-	-	-	-	-	6	4.65	0.98	2.89	4.80	5.66

Table 2 Monthly Aggregate Mortgage Spread as Determined by Aggregate Funding Liquidity, Credit Risk and Interest Rate Variables

This table reports the OLS estimates of monthly aggregate private-label subprime and Alt-A mortgage spread regressed on Treasury convenience yield, normalized ABS/RMBS issuance volume, corporate bond credit spread, lagged subprime/Alt-A mortgage delinquency rate, and change in 10-year Treasury bond rate. Aggregate subprime/Alt-A mortgage spread is the weighted average (weighted by origination loan amount) mortgage spread in each month. Treasury convenience yield is from Feldhutter and Lando (2008) but updated to include data up to 2008. Normalized ABS/RMBS issuance volume is calculated as the private-label ABS/RMBS issuance volume divided by subprime/Alt-A loan origination volume in the prior year. ABS/RMBS issuance volume is from Intex, and mortgage delinquency rate is from the Mortgage Bankers Association (MBA). Credit category is a dummy for Alt-A vs. subprime. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

Mortgage spread over Treasury rate	Estimate [Std. Error]			
	Model 1	Model 2	Model 3	Model 4
Treasury convenience yield	0.295***		0.244***	0.224***
	[0.040]		[0.040]	[0.050]
Normalized ABS/RMBS issuance volume	-0.134**		-0.157***	-0.150***
	[0.040]		[0.038]	[0.042]
Corporate bond credit spread		-0.032	-0.054	0.198**
		[0.045]	[0.034]	[0.064]
Lagged Alt-A/subprime delinquency rate		0.646***	0.416***	0.248*
		[0.143]	[0.114]	[0.123]
Change in 10-year Treasury rate		-0.144***	-0.148***	-0.164***
		[0.041]	[0.032]	[0.028]
Constant	Y	Y	Y	Y
Credit category	Y	Y	Y	Y
Year FE	N	N	N	Y
N	194	194	194	194
Adjusted R^2	0.404	0.435	0.671	0.767

Table 3 Sector Funding Liquidity as Determined by Aggregate Credit Risk and Market Risk Variables

This table reports the OLS estimates of monthly ABS/RMBS issuance volume regressed on Chicago Board Options Exchange VIX and LIBOR credit risk. LIBOR credit risk is from Feldhutter and Lando (2008) but updated to include data up to 2008. Credit category is a dummy for Alt-A vs. subprime. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%.

Normalized ABS/RMBS issuance volume	Estimate [Std. Error]			
	Model 1	Model 2	Model 3	Model 4
VIX	-0.377***		-0.094	0.029
	[0.067]		[0.090]	[0.085]
LIBOR credit risk		-0.466***	-0.400***	-0.377***
		[0.064]	[0.090]	[0.094]
Constant	Y	Y	Y	Y
Credit category	Y	Y	Y	Y
Year FE	N	N	N	Y
N	194	194	194	194
Adjusted R^2	0.147	0.222	0.227	0.620

Table 4 Loan-level Spread as Determined by Funding Liquidity and Credit Risk Variables

This table reports the OLS estimates from the loan-level subprime/Alt-A mortgage spread regression as it depends on our liquidity funding measures as well as credit and prepayment risk factors. Treasury convenience yield is a macro liquidity measure, normalized ABS/RMBS issuance volume is a sector funding liquidity measure, whether a loan is in the prevailing FICO or LTV bucket in the securitization market is a loan-level liquidity measure. Loan characteristics include combined LTV, payment-to-income ratio (PTI), loan size, documentation type, property type, loan purpose, property occupancy type, and prepayment penalty features. Borrower characteristics include borrower FICO score, borrower race and ethnicity, and gender. Lender characteristics include loan type (large vs. small) classified by the lender's market share. Zip code characteristics include percentage of college graduates. All continuous variables are standardized before running the regression, and LTV, PTI and FICO score are in buckets. Standard errors are reported in square brackets. ***, **, * and b for p<0.1%, p<1%, p<5%, and p<10%, respectively.

Loan spread over Treasury rate	Estimate [Std. Error]					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Treasury convenience yield	0.065***			0.057***	0.050***	0.045***
	[0.003]			[0.003]	[0.003]	[0.004]
Normalized ABS/RMBS issuance volume	-0.111***			-0.099***	-0.099***	-0.097***
	[0.003]			[0.003]	[0.002]	[0.003]
In prevailing FICO bucket		-0.226**		-0.540***	-0.728***	-1.028***
		[0.085]		[0.083]	[0.078]	[0.079]
In prevailing LTV bucket		-0.634***		-0.624***	-0.071***	-0.075***
		[0.015]		[0.014]	[0.014]	[0.014]
Corporate bond credit spread			0.136***	0.107***	0.122***	0.280***
			[0.003]	[0.003]	[0.003]	[0.005]
Lagged Alt-A/subprime delinquency rate			0.250***	0.261***	0.235***	0.247***
			[0.012]	[0.012]	[0.011]	[0.013]
Change in 10-year Treasury rate			-0.163***	-0.160***	-0.154***	-0.155***
			[0.002]	[0.002]	[0.002]	[0.002]
Loan characteristics	N	N	N	N	Y	Y
Borrower characteristics	N	N	N	N	Y	Y
Lender characteristics	N	N	N	N	Y	Y
Zip code characteristics	N	N	N	N	Y	Y
MSA FE	N	N	N	N	Y	Y
Vintage FE	N	N	N	N	N	Y
N	160,133	160,133	160,133	160,133	160,133	160,133
Adjusted R^2	0.216	0.243	0.244	0.258	0.377	0.397

Table 5 Loan Performance as Determined by Credit Risk Factors and Liquidity Variables

This table reports the MLE estimates of the hazard model where default hazard rate is a function of the contemporaneous sector-level liquidity variable and the liquidity variable at loan origination, as well as all the control variables. Default is defined as over 60-day delinquency. In model 2, the control variables include loan spread and its square term orthogonalized to our liquidity risk measures (indicated as loan spread ⊥ and square term of loan spread ⊥). In model 4, control variables include negative equity and its square term, change in unemployment rate, and others. Negative equity is calculated based on origination LTV, loan amortization, and property value change based on HPI. Change in unemployment rate is from loan origination to the loan performance quarter. Other control variables include loan, borrower, lender, zip code characteristics, as well as refinance incentive measures. The model is estimated based on the loan performance data in our sample of subprime and Alt-A loans with data up to March 2008, after which the private-label securitization market dried up. Coefficients not reported here are available upon request. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

Default hazard	Estimate [Std. Error]			
	Model 1	Model 2	Model 3	Model 4
Lagged ABS/RMBS issuance volume			-0.072***	-0.114***
			[0.018]	[0.008]
ABS/RMBS issuance volume at loan origination			-0.019*	-0.008
			[0.008]	[0.008]
Loan spread ⊥	0.340***		0.340***	
	[0.007]		[0.007]	
Square term of loan spread ⊥	-0.052***		-0.051***	
	[0.004]		[0.004]	
Negative equity		0.135***		0.115***
		[0.010]		[0.010]
Square term of negative equity		0.002***		0.002***
		[0.000]		[0.000]
Change in unemployment rate		0.050***		0.040***
		[0.009]		[0.008]
Performance quarter FE	Y	N	Y	N
Loan characteristics	N	Y	N	Y
Borrower characteristics	N	Y	N	Y
Lender characteristics	N	Y	N	Y
Zip code characteristics	N	Y	N	Y
MSA FE	N	Y	N	Y
Credit category	Y	Y	Y	Y
Vintage FE	Y	Y	Y	Y
N	2,017,696	2,017,696	2,017,696	2,017,696
-2LogL	877,339	875,538	877,318	875,351
A.I.C.	877,421	875,650	877,404	875,467

Table 6 Differential Impacts of Sector Funding Liquidity on Large- versus Small-remaining Balance Loans

This table reports the MLE estimates of the hazard model that includes an interaction between Lagged ABS/RMBS issuance volume and a dummy variable indicating that the remaining loan balance is above the conforming loan limit (jumbo indicator). It demonstrates the effect of liquidity-driven default, since jumbo size loans are more affected by funding illiquidity in the private-label mortgage market. Control variables in Model 5 and 6 include all those in Table 5, Models 3 and 4, respectively. Standard errors are in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

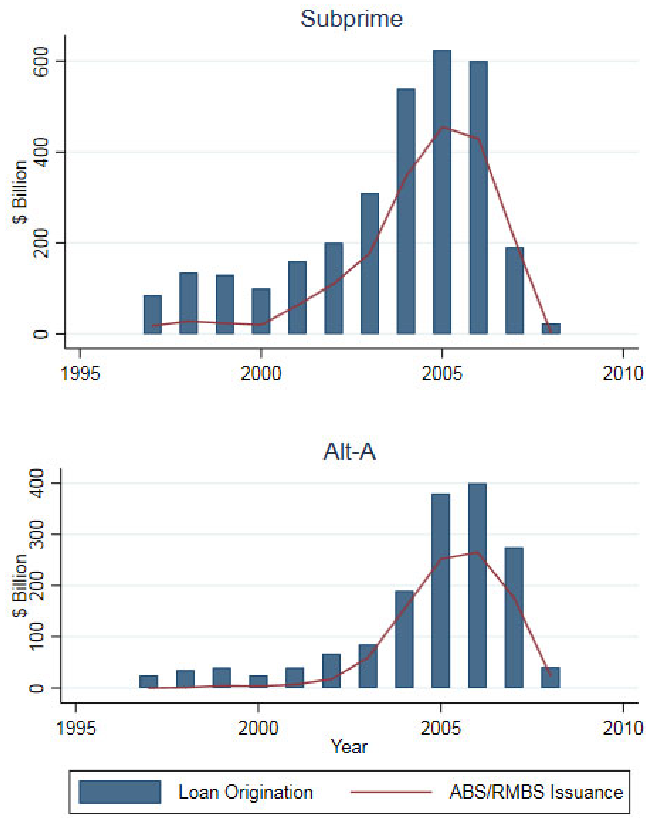
Default hazard	Estimate [Std. Error]	
	Model 5	Model 6
Lagged ABS/RMBS issuance volume	-0.056** [0.018]	-0.107** [0.009]
Lagged ABS/RMBS issuance volume * jumbo remaining balance	-0.144*** [0.021]	-0.100*** [0.024]
Loan spread	Y	N
Square term of loan spread	Y	N
Negative equity	N	Y
Square term of negative equity	N	Y
Change in unemployment rate	N	Y
Performance quarter FE	Y	N
Loan characteristics	N	Y
Borrower characteristics	N	Y
Lender characteristics	N	Y
Zip code characteristics	N	Y
MSA FE	N	Y
Credit category	Y	Y
Vintage FE	Y	Y
N	2,017,696	2,017,696
-2LogL	877,276	875,334
A.I.C.	877,362	875,450

Table 7 Relation between Sector Funding Liquidity and Credit Risk

This table reports the OLS estimates of monthly ABS/RMBS issuance volume regressed on lagged Alt-A/subprime mortgage delinquency rate in the two sub-periods. The 2006.6~2008.1 period is the crisis period when a large number of defaults were observed by market participants. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%.

Normalized ABS/RMBS issuance volume	Estimate [Std. Error]			
	2000.1~2006.5		2006.6~2008.1	
	Alt-A	Subprime	Alt-A	Subprime
Lagged mortgage delinquency rate	6.952	0.049	-9.955***	-1.104***
	[3.068]	[0.196]	[1.170]	[0.209]
Constant	Y	Y	Y	Y
N	74	76	19	19
Adjusted R^2 (%)	0.064	0.001	0.800	0.607

Appendix Figure 1 Subprime and Alt-A Loan Origination and Securities Issuance



Note: data from Intex and Inside Mortgage Finance and aggregated by the authors.

Appendix Table 1 Sample Subprime Mortgage Loan Pricing Menu

This table shows rate quotes for 30-year fixed rate mortgage loans on April 18, 2003, from IndyMac Bank; 2) Stated income is a type of a low documentation loan program; 3) Other lenders apply different cutoff values in FICO score, LTV and backend ratio.

	FICO	LTV	Backend	Mortgage interest rate
Full doc	600 up	<=65	50~55	7.250
		65~70	50~55	7.500
		70~75	50~55	7.625
		75~80	50~55	7.750
		80~85	45~50	8.125
		85~90	45~50	8.375
		90~95	<=45	8.625
	575-599	<=65	50~55	7.875
		65~70	50~55	8.125
		70~75	50~55	8.250
		75~80	50~55	8.375
		80~85	<=50	8.750
		85~90	<=50	9.000
	550-574	<=65	50~55	8.250
		65~70	50~55	8.500
		70~75	50~55	8.625
		75~80	50~55	8.750
		80~85	<=50	9.125
Stated income	600 up	<=65	50~55	7.625
		65~70	50~55	7.875
		70~75	50~55	8.000
		75~80	50~55	8.125
		80~85	<=50	8.500
	575-599	<=65	<=55	8.250
		65~70	<=55	8.500
		70~75	<=55	8.625
		75~80	<=55	8.750
	550-574	<=65	<=55	8.625
		65~70	<=55	8.875
		70~75	<=55	9.000
Second home				+0.500
Non owner occupied				+0.750
2-4 units				+0.250
Low-rise condo				+0.250

Appendix Table 2 Sample Distributions of Our Mortgage Loans

The two panels show distributions of property location by MSA, and loan origination year of the subprime and Alt-A mortgage loans in our sample. All loans are private-label securitized. We limit our analysis to first-lien, 30-year, fixed-rate mortgage (FRM) loans. We further exclude about 10 percent of loans with interest-only (IO) periods or with missing or wrong information on loan origination date, original loan balance, property type, refinance indicator, occupancy status, FICO score, loan-to-value ratio (LTV), documentation level or mortgage note rate. Loans in these 10 major MSAs represent about 25 percent of the national sample.

Panel A: Vintage

	Frequency	Percent	Cum. frequency	Cum. percent
2000	3,123	2.0	3,123	2.0
2001	4,592	2.9	7,715	4.8
2002	7,649	4.8	15,364	9.6
2003	21,861	13.7	37,225	23.3
2004	25,401	15.9	62,626	39.1
2005	37,302	23.3	99,928	62.4
2006	44,522	27.8	144,450	90.2
2007	15,671	9.8	160,121	100.0
2008	12	0.0	160,133	100.0

Panel B: MSA

Atlanta, 12060	10,758	6.7	10,758	6.7
Boston, 14460	7,090	4.4	17,848	11.2
Chicago, 16980	18,091	11.3	35,939	22.4
Dallas, 19100	15,683	9.8	51,622	32.2
Detroit, 19820	9,912	6.2	61,534	38.4
Los Angeles, 31100	24,848	15.5	86,382	53.9
Miami, 33100	23,516	14.7	109,898	68.6
New York, 35620	34,382	21.5	144,280	90.1
Phoenix, 38060	10,113	6.3	154,393	96.4
Washington DC, 47900	5,740	3.6	160,133	100.0

Appendix Table 3 Descriptive Statistics of Mortgage Loan Credit and Prepayment Risk Variables Used in Our Sample

This table reports the descriptive statistics of individual loan characteristics of our subprime and Alt-A mortgage loan sample. These are all 30-year fixed-rate mortgage (FRM) loans. Original loan amount is defined as the amount of principal borrowed as of the closing date of the mortgage. FICO score refers to the FICO (formerly the Fair Isaac Corporation) borrower credit score at the time of the loan closing. LTV (%) refers to the ratio of the original loan amount to the property value at loan origination, while Combined LTV (%) means the ratio of all loan amounts on the property at the time of origination to the property value at loan origination. Payment-to-income ratio refers to the percentage of monthly mortgage payment to borrower's monthly income. Full, low and no documentation are indicators of whether a particular loan has full, low, no or reduced documentation of income, asset or employment information. Single family, PUD (planned-unit development) and condo (condominium) are types of the property securing the mortgage. Loan purpose indicates the primary reason the mortgage was taken out by the borrower, including for home purchase, for rate/term refinance and for cash out refinance. Owner-occupied means the collateral property is the borrower's primary residence, second/vacation home indicates the collateral property is intended to be used as a second home or vacation home, and investment property means the home is intended to be used as an investment. Prepayment penalty type is an indicator denoting that a fee will be charged to the borrower if she elects to make unscheduled principal payments. Large (small) lender is defined as the lender ranked at the 99^{th}(10^{th}) percentile by origination volume in a particular year in a specific MSA.

Variable	Mean	Std Dev	5th Pctl	Median	95th Pctl
Alt-A loan	0.50	0.50	0	1	1
Subprime loan	0.50	0.50	0	0	1
Original loan amount ($)	220,467	143,490	66,000	183,150	493,000
Original term	360	0	360	360	360
Fixed-rate mortgage	1	0	1	1	1
Loan-to-value ratio (LTV, %)	74	16	43	79	95
Combined LTV (%)	75	17	43	80	100
Borrower FICO score	610	42	529	621	657
Payment-to-income ratio	0.23	0.09	0.08	0.23	0.4
Full documentation	0.66	0.47	0	1	1
Low documentation	0.29	0.46	0	0	1
No documentation	0.03	0.16	0	0	0
Reduced documentation	0.01	0.12	0	0	0
Single family property	0.84	0.37	0	1	1
Planned-unit development (PUD)	0.08	0.27	0	0	1
Condominium	0.08	0.28	0	0	1
Cooperative	0.00	0.05	0	0	0
Home purchase	0.20	0.40	0	0	1
Rate/term refinance	0.22	0.42	0	0	1
Cash out refinance	0.57	0.49	0	1	1
Owner-occupied	0.94	0.24	0	1	1
Second/vacation home	0.00	0.07	0	0	0
Investment property	0.06	0.23	0	0	1
Without prepayment penalty	0.03	0.16	0	0	0
With prepayment penalty	0.55	0.50	0	1	1
Prepay penalty clause unknown	0.42	0.49	0	0	1
With second lien	0.17	0.38	0	0	1
Race: White	0.53	0.50	0	1	1
Race: Asian	0.03	0.17	0	0	0
Race: Black or African American	0.20	0.40	0	0	1
Race: other non-white	0.23	0.42	0	0	1
Female borrower	0.35	0.48	0	0	1
Borrower income ($000)	89	74	30	71	201
Zip code college graduate (%)	0.05	0.01	0.03	0.05	0.06
Originated by a large lender	0.24	0.43	0	0	1
Originated by a small lender	0.18	0.39	0	0	1
N			160,133		

Appendix Table 4 The Monthly Aggregate Subprime Mortgage Spread as Determined by Funding Liquidity and Credit Risk Variables, *Change Regression*

This table reports the monthly year-over-year change in aggregate mortgage spread regressed on similarly calculated changes in Treasury convenience yield, normalized ABS/RMBS issuance volume, corporate bond credit spread, lagged subprime/Alt-A mortgage delinquency rate, and change in 10-year Treasury bond rate. Aggregate subprime/Alt-A mortgage spread is the weighted average (weighted by origination loan amount) mortgage spread in each month. Treasury convenience yield is from Feldhutter and Lando (2008) but updated to include data up to 2008. Normalized ABS/RMBS issuance volume is calculated as the private-label ABS/RMBS issuance volume divided by subprime/Alt-A loan origination volume in the prior year. ABS/RMBS issuance volume is from Intex, and mortgage delinquency rate is from the Mortgage Bankers Association (MBA). Credit category is a dummy for Alt-A vs. subprime. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

Δ mortgage spread over Treasury rate	Estimate [Std. Error]			
	Model 1	Model 2	Model 3	Model 4
Δ Treasury convenience yield	0.278***		0.186**	0.135*
	[0.057]		[0.057]	[0.061]
Δ Normalized ABS/RMBS issuance volume	-0.126*		-0.144**	-0.096[b]
	[0.057]		[0.052]	[0.057]
Δ Corporate bond credit spread		0.005	-0.058	0.449***
		[0.053]	[0.051]	[0.091]
Δ Lagged Alt-A/subprime delinquency rate		0.543***	0.400***	0.108
		[0.114]	[0.113]	[0.164]
Δ Change in 10-year Treasury rate		-0.249***	-0.229***	-0.267***
		[0.056]	[0.053]	[0.045]
Constant	Y	Y	Y	Y
Credit category	Y	Y	Y	Y
Year FE	N	N	N	Y
N	182	182	182	182
Adjusted R^2	0.192	0.234	0.331	0.555