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

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ABSTRACT

We study the determinants of the subprime mortgage loan spread, with a particular focus on funding liquidity and default-liquidity interaction effects. We find that sector-level as well as macro funding liquidity provision affected subprime 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. A reduction in macro funding liquidity provision at the time of loan origination predicts worsening credit performance, implying a stabilizing default-driven liquidity component in the loan spread. 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-

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

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 subprime mortgage market provides a natural setting to undertake this type of exercise. From 2000 to 2006 funding liquidity in the subprime mortgage market was plentiful. Subprime mortgage loans were easily saleable into a secondary market where they were used to collateralize higher-rated mortgage-backed securities (MBS) 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 subprime MBS prices spiked and liquidity began to recede from the market. Without liquidity in the secondary market subprime 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) subprime households to obtain financing sidelined an entire market of potential homebuyers to further depress house prices in subprime neighborhoods.[3] As a consequence of these dynamics, along with certain other contributing factors, large waves of subprime 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 subprime 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

[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).

the subprime mortgage market, and vice versa, thus providing evidence of spiraling as funding liquidity and credit risks fed back on one another.

We develop two measures of funding liquidity. First, we follow the literature by using the LIBOR swap spread 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 subprime mortgage loans that were originated and sold into the secondary market: subprime ABS issuance volume.

We find that the subprime mortgage spread is sensitive to both measures of funding liquidity, where these two factors alone explain about 23 percent of the time variation in aggregate spread. Then, after introducing a battery of loan level credit risk controls, in the cross-section funding liquidity alone explains over 16 percent of the variation in subprime mortgage spread. With a subprime mortgage spread averaged 360 basis points over our sample period, we estimate a lower bound of 17 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. As a preliminary step in this analysis we document that the credit component of the subprime mortgage spread is predictive of future credit performance, as one would expect given rational expectations.

Our most novel findings pertain to the interactions between liquidity and credit risks. After controlling for borrower solvency risks and numerous other credit risk factors, we document that borrower liquidity risk is an important determinant of credit performance. That is, we identify a 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 sector-level funding illiquidity had greater negative effects on credit outcomes in the jumbo mortgage market, for which there was very little liquidity provision from 2008 onward.

Whereas liquidity-driven default is thought to be destabilizing, Chen (2010) and Huang and Huang (2012) argue that business cycles and rational expectations imply the loan spread contains a countercyclical stabilizing consumption risk component. We use the LIBOR swap spread *at loan origination* to measure the hypothesized risk premium, where the idea is that clustering of loan defaults during a recession is not only a concern of bond investors but also of banks and the banking system more broadly. We find that the LIBOR swap spread at loan origination to be predictive of subprime mortgage credit performance, where reductions in macro funding liquidity at loan origination, which produces a marginally higher loan rate, forecasts higher rates of mortgage default. The effect is stabilizing because, as investors anticipate that deterioration in economic conditions today might cause a future recession, and therefore an increased likelihood of bond default at a time when the marginal utility of consumption is high, a default-driven liquidity premium at loan origination is included as a form of consumption insurance for investors.

In contrast to the swap spread-credit performance relationship, we find that greater sector-level liquidity provision in the form of subprime ABS issuance volume at loan origination correlates negatively with credit performance, indicating a destabilizing effect. Although this procyclical relationship has been much discussed in the press and policy circles, with a variety of hypothesized causes, we believe we are the first to successfully isolate the effect empirically.

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 subprime mortgage default. In particular, the lagged subprime mortgage delinquency rate is highly predictive of and negatively related to current subprime ABS issuance volume, suggesting a procyclical 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 subprime mortgage default caused ABS investors to retreat from the subprime secondary mortgage market, which in turn caused funding illiquidity in the primary subprime 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 subprime mortgage loans, and so on and so forth.

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 that are typically omitted in studies of corporate bond pricing. 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. In contrast, corporate bonds tend to utilize heterogeneous contract clauses and covenants that introduce variation that is difficult to categorize and control for. The foreclosure and bankruptcy process is generally more streamlined with consumers than with corporations, typically with fewer agency problems associated with generating collective action outcomes. All together we believe our data suffer from fewer omitted variable and endogeneity problems than corporate bond data, leading to cleaner identification of bond pricing factors. Finally, our sample size dwarfs that available in the corporate sector.

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.[4]

The rest of the paper is organized as follows. In the next section we discuss salient features of subprime 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 characterize the data. In section four we assess the time series and cross-sectional determinants of the subprime 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. Subprime Mortgage Loan Origination, Loan Pricing, and Securitization

Subprime loans in our data were identified as such by the originating lender, creating the basis for our sample. Subprime 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. The subprime 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, collateral-locational characteristics, and sometimes other factors such as loan type (e.g., option-ARM) or verification criteria (e.g., no income/asset verification).

[4] 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.

Subprime loan rates at the time of origination is "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.[5] 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 loans we analyze were sold into the secondary mortgage market to be used as collateral for private-label MBS. The development of a secondary market for subprime mortgage loans greatly enhanced liquidity in the origination market. Figure 1 shows subprime mortgage loan origination and securitization volume as well as the rate of subprime mortgage loan securitization. Visual inspection shows a clear strong relation between subprime MBS issuance and subprime mortgage origination volume. Note also that the volume of subprime securitization is seen to accelerate starting in 2001. Then, as the housing market peaked in 2006 and mortgage default rates of subprime loans started to spike, leading to significant volatility and then sharp declines in MBS prices, secondary market liquidity dried up as investors lost their appetite for these securities. Without secondary market liquidity the primary channel for subprime loan origination also dried up, and with it the ability of financially constrained subprime borrowers to purchase houses.

FIGURE 1 HERE

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

[5] As we will show later in the paper, many subprime mortgage loans carry prepayment penalties that limit prepayment risk.

loan rates at origination to reliably measure the mortgage loan's true price, for this study we consider only 30-year fixed rate subprime mortgage loans.[6]

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 subprime mortgage pricing at origination.[7]

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 subprime 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. (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*.

[6] Subprime 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 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)).

[7] 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. This is 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.

Furthermore, given our focus on the use of debt (the subprime 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 subprime borrower-lending sector. We will be more precise in the next section as to our exact empirical measures of macro and sector-level funding liquidity.[8]

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 *stabilizing* or *destabilizing effects* as they interact with other factors, particularly credit risks. Chen, Collin-Dufresne and Goldstein (2009) and Chen (2010) argue that business cycles and rational expectations generate credit risk premia that act as consumption insurance for investors. The effect is countercyclical and thus stabilizing, and may be channeled based on funding liquidity provision at the time of loan issuance. Destabilizing liquidity provision is taken up in recent bond pricing literature, where 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 spiraling, when procyclical liquidity provision intensifies default outcomes which in turn results in further reductions in liquidity.

[8] 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.

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

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 1998 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, which covers the period through which the majority of defaults occurred as a result of the downturn in housing prices and associated effects of the Great Recession.

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.[9]

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 mortgage loans originated in 10 large U.S. metropolitan statistical areas (MSA's). These MSA's are New York, Los Angeles, Chicago, Dallas, Miami, Detroit, Atlanta, Boston, Las Vegas and Washington DC.[10] 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

[9] 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.

[10] A series of filters are also applied. In particular we exclude loans originated before 1998, 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.

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 subprime MBS issuance volume to gauge sector-level funding liquidity of subprime mortgage loan originations. These data are subprime mortgage asset-backed security (ABS) issuance figures as generated by ABAlert. ABAlert provides weekly updates on ABS issuance across a number of countries, and is the most comprehensive data source available on new ABS issuances. To generate monthly subprime ABS volume we aggregate ABS issued in U.S. in which subprime mortgage loans are identified as collateral.

Following the literature we use the 10-year LIBOR interest rate swap spread (the difference between the 10-year LIBOR swap rate and 10-year Treasury yield) to measure macro liquidity funding provision as it applies to the long-maturity mortgage loans utilized in this study. Changes in the 10-year LIBOR swap 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. As discussed by Huang, Neftei and Jersey (2003) and Hou and Skeie (2014), numerous studies have attempted to measure the contribution of the constituent parts to the LIBOR swap spread, where the majority view is the liquidity risk component dominates.[11]

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 subprime mortgage delinquency rate from the Mortgage Bankers Association (MBA). The MBA's quarterly delinquency survey provides separate treatment of fixed-rate (FRM) and adjustable-rate mortgages (ARM), allowing us to specifically identify the 60-day delinquency rate of subprime FRMs.

[11] See, also, International Financing Review, June 29, 2002.

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 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 86,926 30-year FRMs that are classified by the lender as "subprime". Panel A of Table 1 shows the FICO score distribution of our sample. Consistent with the notion that subprime mortgage loans are available primarily to borrowers that fail to qualify for prime mortgage loans, 97 percent of borrowers in our sample have a FICO score at origination below 620—the traditional lower bound cutoff for a prime loan. Nearly 47 percent of borrowers in our sample have a very low FICO score of less than 580, and nearly 17 percent have FICO scores of 540 or less. Note, however, that some borrowers have relatively high FICO scores greater than 700. In these cases other borrower or loan/collateral characteristics cause the loan to be classified as "subprime".

TABLE 1 HERE

In Panel B of Table 1 we report the geographic distribution of loans in our sample. Altogether, the 30-year subprime FRM loans in our 10 MSA sample represent almost 25 percent of the national total of such mortgages. Panel C of Table 1 shows the origination year distribution of the loan sample. While only 599 subprime mortgages (less than 1 percent of the sample) were originated in 1998, that number grew to over 10,000 in 2003 and then peaked at 23,709 in 2006. A sharp decline in subprime origination ensued with the onset of the crisis in 2007, with less than 10,000 loans originated in 2007 and only 32 FRM subprime loans originated in 2008.

Panel A of Table 2 displays summary statistics of the mortgage interest rate in our loan sample. The average rate over the entire sample period is 8.16 percent, which is well above the average note rate on 30-year prime FRMs of about 6.6 percent during our study period.[12] Over time there

[12] Freddie Mac mortgage interest rate survey.

is significant variation in the average note rate, due to either changes in the base rate or changes in the mortgage spread, or both.

TABLE 2 HERE

Panel B of Table 2 reports summary statistics of 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 360 bps. Large time variation in the mortgage spread is seen in the data. From 1998 to 2001 the spread is seen to generally increase, followed by a general decline from 2001 to 2004-05. Mortgage spreads begin to gap out in 2006 with large year-over-year increases in 2007 and 2008.

4. Funding Liquidity and the Subprime Mortgage Spread

4.1. Sector-Level and Macro 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. Rather, we focus on a quantity-based measure of sector-specific liquidity—the new issuance of subprime ABS. The idea behind this measure is that greater issuance volume implies a stronger investor appetite for securities backed by subprime mortgage loans, and hence greater secondary market liquidity of the mortgage loans themselves (recall Figure 1). Private-label securitization created a secondary market for subprime mortgage loans, and therefore liquidity to fund financially constrained subprime borrowers.

Figure 2 displays monthly subprime ABS issuance volume from January 1998 to February 2008. Prior to 2001 the monthly issuance volume was typically in the $5 billion range, but by 2006 it reached over $40 billion. On the same chart, we plot the average subprime mortgage spread. Visual inspection suggests that during the 2001 to 2005 time period there tended to be a negative relation between subprime mortgage spread and subprime ABS issuance volume, with a less clearly delineated relation in the early and later sample period.

FIGURE 2 HERE

We use the average monthly interest rate swap spread as our primary macro liquidity risk measure (see., e.g., Duffie and Singleton, 1997; Huang, Neftei and Jersey, 2003). The interest rate swap spread is defined as the difference between the 10-year swap rate of LIBOR and the yield of the 10-year Treasury. As such the swap spread is a broad-based measure of bank liquidity provision, and therefore provides a measure of funding liquidity, where a higher swap spread implies a reduction in macro funding liquidity provision. The swap spread is plotted in Figure 2. Notice that the time-series pattern of the swap spread is very different from the subprime ABS issuance time-series also shown in Figure 2 (the time series correlation between the two variables is 0.20), suggesting that it is relevant to distinguish macro from sector-level funding liquidity.

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

To begin to explore the connection between funding liquidity provision and subprime mortgage pricing we first calculate the weighted average mortgage spread in each month of loan origination, and then regress the average spread on our two funding liquidity measures as well as the aggregate credit risk measures. The aggregate credit risk measures include the corporate bond credit spread and the fixed-rate subprime mortgage default rate (with a lag). We also include change in the 10-year Treasury rate to account for prepayment risk effects. The time series of these three variables are displayed in Figure 3 and summary statistics are reported in Table 3.

FIGURE 3 AND TABLE 3 HERE

The resulting regression takes the following form:

$$r_t = \alpha + L_t\beta + Z_t\gamma + \varepsilon_t,\ t = 1, \ldots T \quad (1)$$

where r_t indicates the average mortgage spread, L_t denotes macro and sector-level funding liquidity measures, Z_t indicates the aggregate credit and prepayment risk factors, and ε_t is the disturbance term. ABS issuance volume is calculated as the log of the 3-month moving average, and fixed-rate subprime mortgage default rate is with a one-quarter lag where default rates are reported on a quarterly basis.[13]

Regression results are reported in Table 4. 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 swap spread, implying a reduction in macro funding liquidity provision, is associated with a higher mortgage spread, while higher ABS issuance volume, implying greater sector-level funding liquidity, is associated with a lower mortgage spread. The adjusted-R^2 is about 23 percent.

TABLE 4 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 subprime mortgage default rate implies 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 28 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 50 percent. As a robustness check, to address spurious time-series regression concerns, we take first-order differences in the dependent and all independent variables

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

and run the *change* regression. Results reported in Appendix Table 2 indicate that our initial findings are robust.[14]

Next, we explore the relation between subprime ABS issuance volume and the subprime delinquency rate, as well as the VIX which serves as a broader measure of market risk (see, e.g., Bao, Pan and Wang, 2011). Table 5 contains our regression results. Interestingly, we see that over our entire study period, January 1998 to May 2008, ABS issuance volume and the lagged default rate have at best a tenuous negative relationship. In contrast, VIX, a "fear gauge" of the market, is highly correlated with ABS issuance volume. We interpret the VIX result as helping validate our use of ABS issuance volume as a funding liquidity risk measure.

TABLE 5 HERE

4.3. Funding Liquidity and Loan-Level Mortgage Spread

In this section we incorporate the detailed information we have for each subprime mortgage loan in our sample. This allows us to control for borrower, housing collateral and loan contracting variables that might correlate with our broader measures of funding liquidity risks. The cross-sectional variation introduced into the regression also aids in identification.

With the introduction of cross-sectional variation the mortgage spread regression takes the following form:

$$r_{i,t} = \alpha + L_t\beta + Z_t\gamma + X_{i,t}\delta + \varepsilon_{i,t},\ i = 1, \ldots N;\ t = 1, \ldots T \qquad (2)$$

Here $r_{i,t}$ is the subprime mortgage spread for loan *i* originated at time *t*, L_t, our funding liquidity measures, Z_t, our aggregate credit and prepayment risk measures, $X_{i,t}$, a vector of loan-level credit and prepayment risk factors that we will discuss in more detail below, and $\varepsilon_{i,t}$, is the disturbance term. As before, time increments are monthly unless otherwise indicated.

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

The $X_{i,t}$ 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 for the census track where the housing collateral is located. 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 subprime mortgage market, lenders with lower funding and/or operational costs could have offered better rates to their borrowers. With this in mind we classify lenders as small, medium and large as measured by their subprime loan production on an annual basis. For the large lender category we identify the top one percent—the very largest lenders based on subprime loan production.[15] Small lenders are identified as the bottom 10 percent in subprime origination volume in a particular year.

Finally, in all model specifications we control for collateral location by including MSA dummy variables. Also, 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 variables to indicate particular size or timing ranges for combined LTV and prepayment penalty/lockout period, respectively.

In Table 6, we report summary statistics for the aforementioned loan-level credit and prepayment risk factors as well as lender size categories. Table 7 contains the loan-level mortgage spread regression results. In model 1, besides MSA-fixed effects, we only include our macro and sector-level funding liquidity measures. Results are consistent with those found in our previous analysis. In particular, the LIBOR swap spread is positively related with mortgage spread and subprime

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

ABS issuance volume is negatively related with mortgage spread, implying that increased funding liquidity provision at the macro as well as sector level causes the subprime mortgage spread to compress. The adjusted-R^2 from the regression is slightly over 16 percent.

TABLES 6 AND 7 HERE

In model 2, 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 3, 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 4, 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 generally have the expected signs. For example, all else equal a higher FICO score reduces the subprime 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 just over 30 percent of the variation in the mortgage spread is explained.

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 (LIBOR swap rate) and sector-level (ABS 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 107 basis points. Given that the range of the total mortgage spread is 629 basis points, these estimates imply that, as a conservative estimate, the liquidity premium contributes approximately 17 percent (107÷629=0.17) 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

A crucial aspect of our subprime mortgage data is that it allows 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 event, should such an event occur in the data. In contrast, other empirical studies of the corporate bond spread 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 current 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:

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

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.[16] Covariates are indicated by $Z_{i,t}$, which can be static or time varying, and which result in proportional shifts in the

[16] Notice that the loan duration time T is different from the natural time t, which allows identification of the model.

hazard rate without otherwise affecting the duration pattern of default. For our purposes a default event is defined as over 60 day's delinquent.

In Table 8 we identify and provide summary statistics for new variables that will be considered in hazard model estimation, where there are over 2.0 million quarterly loan records in our sample. Volatility adjusted 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), divided by house price return volatility. It 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). The positive mean value indicates that many of the loans in our sample were underwater at least at some point during their lives.

TABLE 8 HERE

Refinance incentive 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. 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.[17] The average MSA-level unemployment rate increased by 1.7 percent from the loan origination quarter to the current quarter. The one-month lagged subprime ABS issuance and the lagged LIBOR swap spread are included to gauge current funding liquidity conditions on credit performance.

[17] An, Deng and Gabriel (2015) shows that this variable serves as a good proxy of borrower income change in a hazard model.

5.1. Preliminaries: Does the Mortgage Loan Spread Predict Credit Performance?

As a preliminary exercise, we consider whether the mortgage spread at loan origination is predictive of mortgage default. The idea is straightforward: If the mortgage spread at loan issuance contains information about credit risk, it should be predictive of realized credit performance. This is indeed what we find, with results reported in Table 9, Model 1. In this specification the mortgage spread and its square term are the only covariates we include in the hazard model. The coefficient on the spread term is positive and statistically significant, while that of the square term is insignificant.

In the next test we first orthogonalize mortgage spread to our two funding liquidity measures—the LIBOR swap spread and ABS issuance volume. The purpose of this exercise is to try to isolate the credit component of the mortgage spread from the funding liquidity component. To do this we take the residuals from a first-stage regression as specified in Table 4, Model 1, and then place the orthogonalized spread (spread$^{\perp}$) and its square term into the hazard model. Results are shown under Model 2, in Table 9. Again the spread term is positive and significant while the squared term is insignificant. We note that the improved model fit generated from this two-stage process suggests that the loan spread in fact contains a "pure" liquidity component that is distinct from the credit spread component.

TABLE 9 HERE

5.2. Loan Level Controls

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 introduced in Table 8. Recall that the latter set of variables include a measure of the contemporaneous net equity position of the borrower (volatility-adjusted negative equity), a proxy for the borrower's own liquidity risk (change in the MSA-level unemployment rate), and contemporaneous funding liquidity metrics. We also interact the refinance incentive variable identified in Table 8 with prepayment penalty

information in order to provide a more refined measure of prepayment's potential effect on credit outcomes.

In our first specification we exclude macro and sector-level funding liquidity variables, referring to it as the baseline model. Estimation results are reported Table 10, model 1, with findings that generally conform with expectations. For example, higher initial LTV ratios, where LTV varies inversely with the borrower's net equity position in the house at the time of loan origination, increase the hazard rate of default. The contemporaneous measure of the borrower's solvency-based default option is the volatility-adjusted negative equity variable. This variable 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. We note that our measure of volatility-adjusted negative equity is based on a local Case-Shiller repeat-sales house price index, which reflects current housing asset pricing conditions. Consequently, to the extent that asset market liquidity effects are relevant in the transaction market, they are incorporated into this solvency measure.

TABLE 10 HERE

While equity's effect on mortgage credit performance has been well documented, borrower liquidity effects are less well understood. With this in mind, first observe 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.[18]

[18] 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

5.3. Default-Liquidity Interaction Effects and Business Cycle Credit Risk Premia

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. Kiyotaki and Moore (1997) take this idea and incorporate it into a dynamic model to generate the basic intuition for default-driven funding liquidity. In their model a negative real shock depresses levered asset values that collateralize the debt, which then leads to reductions in the liquidity available to fund investment going forward.

There is an additional form of default-driven liquidity that we exam that is based on business cycles and rational expectations. The effect, which has been highlighted by Chen, Collin-Dufresne and Goldstein (2009), Chen (2010) and Huang and Huang (2012), works as follows. When, as the result of a negative shock, investors anticipate loan defaults to cluster in the future at a time when the marginal utility of consumption is high, the current loan interest rate increases in response, providing a type of consumption insurance. This effect is distinct from standard credit risk adjustments, which function like an actuarial default-credit risk premium calculation.

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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.

Disentangling the two credit effects is an empirical challenge, however. We will attempt to identify the business cycle component as channeled through our liquidity funding variables, with a particular focus on the LIBOR swap spread as our measure of macro funding liquidity. The idea is that clustering of loan defaults at a time when a recession is likely is also a concern of banks and the banking system, with LIBOR rates responding appropriately. It is in that sense that the effect is interactive, being a particular type of default-driven liquidity response.

Using our subprime mortgage data we now conduct a series of tests to assess these hypothesized effects. We first test for the destabilizing effects of funding liquidity-driven default. The simple test we devise is to add contemporaneous (one-quarter lagged) funding liquidity measures described in Table 8 into the default hazard model 1 in Table 10. Estimation results are shown in Table 11 under model 2.

TABLE 11 HERE

Both funding liquidity variables are significant, where the LIBOR swap spread has a positive sign and ABS issuance volume has negative sign. Widening in the swap rate spread indicates a reduction in macro funding liquidity provision, leading to greater deterioration in sector credit conditions. Likewise, at the sector level, illiquidity in the subprime ABS issuance market causes subprime lenders to refrain from originating new loans, which 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 loans. Jumbo loans, which are considered to be non-conforming, can be sold into Non-Agency MBS but cannot be purchased by Fannie Mae or Freddie Mac. 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.

The baseline model is 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—ABS issuance volume. With results reported in Table 12 under Model 3, 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 12 HERE

We now consider the hypothesized forward-looking default-driven liquidity effect resulting from business cycles and consumption-timing risks. To test for this effect we add macro and sector-level funding liquidity variables measured *at loan origination* to the default hazard model. The hypothesized default-driven funding liquidity effect implies that, in response to a negative shock that is anticipated to adversely affect credit outcomes in the future at a time when the marginal utility of consumption is high, a reduction in funding liquidity provision occurs at loan origination to generate a marginally higher fixed loan rate.

Results of this test are reported in Table 11 under model 4. The swap spread at loan origination is positive and significant, which we take as evidence of a stabilizing default-driven liquidity component in the loan spread. To the extent that LIBOR incorporates business cycle-consumption insurance effects, we believe we are the first to provide independent evidence of the existence of the effect as channeled through loan prices.

In contrast, the coefficient of subprime ABS issuance volume at loan origination is positive and significant, implying that sector-level funding liquidity at loan origination is predictive of default,

but in the opposite direction. In other words, subprime ABS issuance volume is found to be procyclical and destabilizing, serving to reduce mortgage rates at loan origination only to result in higher rates of default later on. The reasons underlying this relationship are not exactly clear, with a number competing explanations that include foreign capital inflows, distortionary housing finance policy and bank regulation, alleged fraud and misrepresentation by securities issuers, and investor over-optimism (see, e.g., Caberello and Krishmurthy. 2006; Agarwal et al, 2012; Piskorski, Seru, and Witkin. 2014; Demyanyk and Van Hemert, 2011; Cheng, Raina and Xiong. 2014). In any case, to our knowledge we are the first to isolate the effect through a rigorous econometric analysis.

Lastly, to address possible concerns regarding the dearth of subprime ABS issuance volume after 2008, we re-estimate models 2 and 4 using loan performance data only through 2008. Results are reported in Table 11, where we see that earlier results are robust to a shortened loan performance sample period.

5.4. 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 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 issuance volume on lagged subprime mortgage delinquency rate using data from January 2006 to May 2008. Estimation results are reported in Table 13, model 1.

TABLE 13 HERE

Recall that we conducted a similar regression previously in section 4 using the full sample of loan origination data going from January 1998 to May 2008. With that sample we found a weak relation between lagged delinquency rate and subprime ABS issuance volume. In the current regression, 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 lagged delinquency rate and subprime ABS issuance volume to be strong. That is, subprime ABS issuance volume dropped when the lagged delinquency rate increased. Notably, variation in the lagged delinquency rate itself helps explain almost 40 percent of variation in subprime ABS issuance volume. When we add VIX, a market-based "fear gauge", into the regression (Table 14 model 2), about 47 percent of the variation in subprime ABS issuance is explained during this critical time period during which destabilizing spiraling effects began to be propagated.

In contrast to our findings of stabilizing default-driven liquidity effects as measured by the swap spread at loan origination, 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. In particular, when Non-Agency MBS investors saw increasing numbers of subprime mortgage defaults, they began to lose their appetite for investment. Illiquidity in the secondary market then caused subprime 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 and so forth.

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 subprime mortgage loans originated between 1998 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 and sector-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 23 percent of the time variation in aggregate subprime mortgage spread, which is similar to the estimate in Bao, Pan and Wang (2011). We also find the liquidity premium to be in excess of 17 percent of total subprime 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, where the latter effect can be stabilizing or destabilizing depending on how it is channeled. Macro funding liquidity is found to be stabilizing based on the predictive power of LIBOR swap spreads at loan origination on credit performance. We interpret this result as supporting predictions of Chen, Collin-Dufresne and Goldstein (2009) and Chen (2010) as to the existence of an intertemporal consumption insurance component in the loan spread. 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 subprime MBS market. This in turn reduced liquidity in the subprime mortgage market, causing defaults to increase, resulting in further reductions in sector-level funding liquidity, and so on and so forth.

We do document one "anomalous" result, which is that increases in our measure of sector-level funding liquidity provision—subprime ABS issuance volume at the time of loan origination—forecasts an increased hazard rate of default. The underlying reasons for this procyclical relationship are not entirely clear to us, but are likely due to the unique structural circumstances associated with subprime lending and securitization that occurred during the early and middle 2000s.

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.

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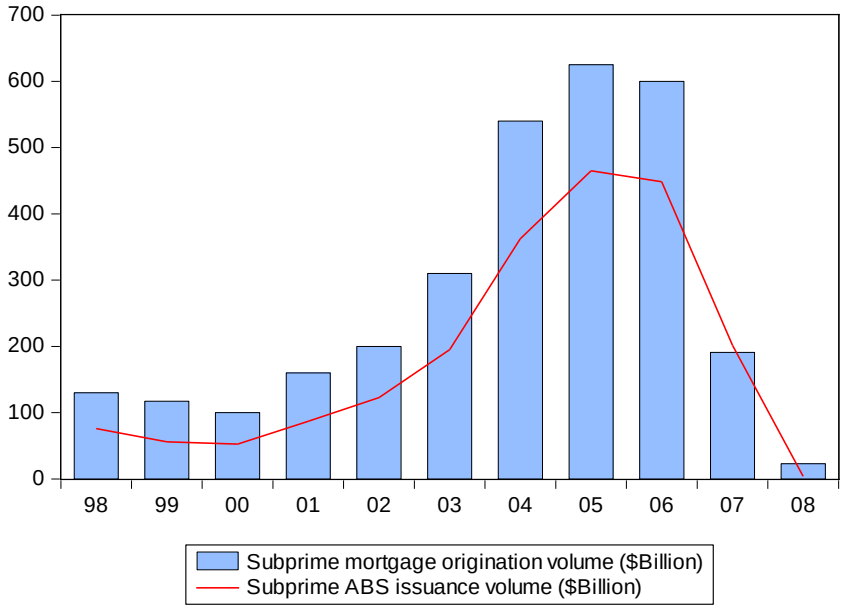
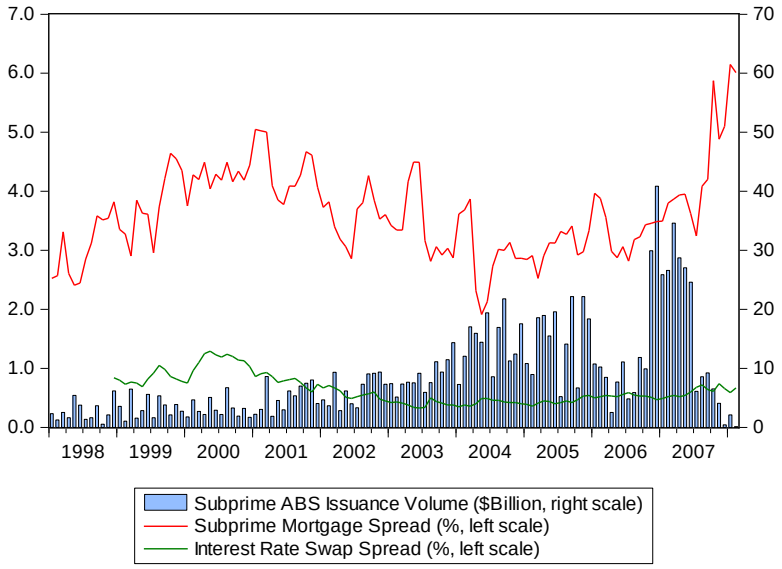
Figure 1: Annual Subprime Mortgage Origination Volume and Subprime ABS Issuance Volume



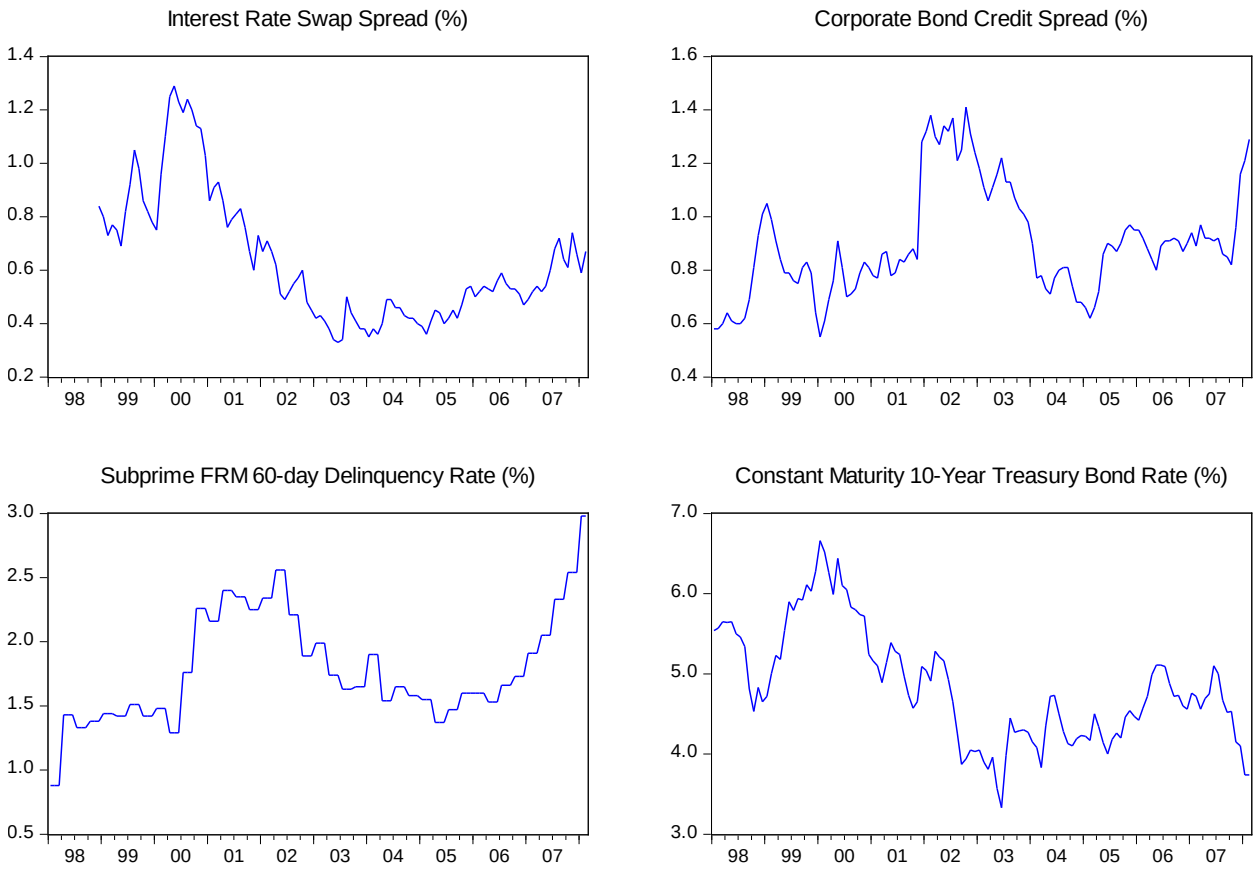
Note: Based on author's data compiled from public sources

Figure 2: Monthly Subprime Mortgage Spread, Swap Spread and ABS Issuance Volume



Note: The Subprime ABS issuance volume is calculated based on data from ABAlert; subrime mortgage spread is calculated based on our mortgage loan data; and interest rate swap spread is calculated based on interest rate swap rate data from St. Louis Fed and the Treasury rate data from the Federal Reserve Board.

Figure 3: Macro Liquidity, Aggregate Credit and Prepayment Risk Factors



Note: Interest rate swap spread is calculated based on interest rate swap rate data from St. Louis Fed and the Treasury rate data from the Federal Reserve Board; corporate bond spread is calculated based on corporate bond yield data from the Federal Reserve Board (originally from Moody's); subprime delinquency rate is from the Mortgage Banks Association; and the 10-year Treasury bond rate is from the Federal Reserve Board. Subprime delinquency rate is at quarterly frequency. Other data are monthly.

Table 1: Sample Distributions of Our Subprime Mortgage Loans

The three panels show distributions of borrower FICO score, property location by MSA, and loan origination year of the subprime 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: FICO score	Frequency	Percent	Cum. Freq.	Cum. Pct.
<540	14,718	16.93	14,718	16.93
540~580	26,053	29.97	40,771	46.90
580~620	43,633	50.20	84,404	97.10
620~660	1,153	1.33	85,557	98.43
660~700	1,037	1.19	86,594	99.62
>700	332	0.38	86,926	100.00
Panel B: MSA				
Atlanta, 12060	5,956	6.85	5,956	6.85
Boston, 14460	3,822	4.40	9,778	11.25
Chicago, 16980	10,349	11.91	20,127	23.15
Dallas, 19100	9,706	11.17	29,833	34.32
Detroit, 19820	6,683	7.69	36,516	42.01
Los Angeles, 31100	11,065	12.73	47,581	54.74
Miami, 33100	13,238	15.23	60,819	69.97
New York, 35620	18,272	21.02	79,091	90.99
Phoenix, 38060	4,879	5.61	83,970	96.60
Washington DC, 47900	2,956	3.40	86,926	100.00
Panel C: Origination year				
1998	599	0.69	599	0.69
1999	1,151	1.32	1,750	2.01
2000	1,983	2.28	3,733	4.29
2001	2,724	3.13	6,457	7.43
2002	3,620	4.16	10,077	11.59
2003	9,824	11.30	19,901	22.89

2004	13,338	15.34	33,239	38.24
2005	20,004	23.01	53,243	61.25
2006	23,709	27.27	76,952	88.53
2007	9,942	11.44	86,894	99.96
2008	32	0.04	86,926	100.00

Table 2: Interest Rate and Mortgage Spread of Our Subprime Loan Sample, by Year of Origination

This table presents descriptive statistics of the note rate of the fixed-rate subprime mortgage loans in our sample. It also shows the descriptive statistics of the mortgage spread, which is the mortgage note rate over comparable maturity 10-year Treasury rate. The statistics are shown for all loans and for each vintage.

Panel A: Subprime Mortgage Interest Rate

		Note rate (%)				
Year	N	Mean	STD	5th Pctl.	Median	95th Pctl.
1998-2008	86,926	8.16	1.49	6.18	7.93	10.92
1998	599	8.97	1.83	6.90	8.55	12.27
1999	1,151	10.49	1.76	7.56	10.53	13.26
2000	1,983	10.57	1.51	8.10	10.56	13.09
2001	2,724	9.71	1.50	7.20	9.71	12.19
2002	3,620	8.49	1.49	6.39	8.34	11.22
2003	9,824	7.70	1.26	5.91	7.54	9.92
2004	13,338	7.43	1.18	5.80	7.28	9.59
2005	20,004	7.62	1.13	6.11	7.45	9.77
2006	23,709	8.37	1.33	6.56	8.23	10.68
2007	9,942	8.79	1.48	6.74	8.72	11.19
2008	32	9.82	0.88	7.90	9.71	11.66

Panel B: Subprime Mortgage Spread over the Treasury Rate

		Spread over Treasury rate (%)				
Year	N	Mean	STD	5th Pctl.	Median	95th Pctl.
1998-2008	86,926	3.60	1.39	1.69	3.43	6.08
1998	599	3.75	1.89	1.40	3.33	7.30

1999	1,151	4.61	1.65	2.07	4.58	7.30
2000	1,983	4.55	1.49	2.14	4.55	7.00
2001	2,724	4.69	1.51	2.11	4.70	7.15
2002	3,620	3.97	1.47	1.81	3.82	6.64
2003	9,824	3.66	1.36	1.75	3.49	6.07
2004	13,338	3.13	1.27	1.29	2.99	5.47
2005	20,004	3.33	1.13	1.81	3.17	5.44
2006	23,709	3.56	1.36	1.66	3.44	5.93
2007	9,942	4.03	1.49	1.96	3.98	6.44
2008	32	6.11	0.86	4.16	5.97	7.92

Table 3: Descriptive Statistics of Monthly Time Series for Aggregate Funding Liquidity, Credit Risk, and Other Market Variables

This table contains descriptive statistics of the time series for aggregate liquidity, credit risk and market risk measures. Subprime ABS issuance volume is calculated based on data from ABAlert; interest rate swap spread is calculated based on interest rate swap rate data from St. Louis Fed and the Treasury rate data from the Federal Reserve Board; corporate bond spread is calculated based on corporate bond yield data from the Federal Reserve Board (originally from Moody's); subprime delinquency rate is from the Mortgage Banks Association; 10-year Treasury bond rate is from the Federal Reserve Board; and the Chicago Board Options Exchange Volatility Index is from CBOE.

	Mean	Std. Dev.	Minimum	Maximum
Subprime ABS issuance volume ($million)	8,607	7,736	0	40,858
Interest rate swap spread	0.64	0.24	0.33	1.29
Corporate bond credit spread	0.91	0.21	0.55	1.41
Subprime fixed-rate mortgage delinquency rate	1.81	0.45	0.88	3.14
Change in 10-year Treasury rate	-0.02	0.22	-0.53	0.65
Chicago Board Options Exchange Volatility Index (CBOE VIX)	20.82	6.66	10.82	38.20
N	122			

Table 4: Monthly Aggregate Subprime Mortgage Spread as Determined by Aggregate Funding Liquidity, Credit Risk and Interest Rate Variables

This table reports monthly aggregate subprime mortgage spread regressed on interest rate swap spread, 3-month moving average of subprime ABS issuance volume, corporate credit spread, lagged subprime fixed- rate mortgage delinquency rate, and change in 10-year Treasury bond rate. Aggregate subprime mortgage spread is the weighted average (weighted by origination loan amount) subprime mortgage spread in each month. Subprime ABS issuance volume is from ABAlert, and subprime mortgage delinquency rate is from the Mortgage Bankers Association (MBA). Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

	Spread over Treasury rate		
	Model 1	Model 2	Model 3
Intercept	3.671*** [0.065]	3.671*** [0.063]	3.671*** [0.052]
Interest rate swap spread	0.248*** [0.071]		0.338*** [0.060]
Log subprime ABS issuance volume, three months moving average	-0.339*** [0.065]		-0.271*** [0.054]
Corporate bond credit spread		-0.028 [0.081]	0.078 [0.069]
Lagged subprime fixed-rate mortgage delinquency rate		0.424*** [0.082]	0.371*** [0.069]
Change in 10-year Treasury rate		-0.139* [0.064]	-0.111* [0.053]
Adjusted R^2 (%)	23.30	27.67	50.49

Table 5: Sector Funding Liquidity as Determined by Aggregate Credit Risk and Market Risk Variables

This table reports monthly subprime ABS issuance volume (in log) regressed on lagged 30-year subprime fixed-rate mortgage delinquency rate and CBOE VIX. Subprime ABS issuance volume is from ABAlert, and subprime mortgage delinquency rate is from the Mortgage Bankers

Association (MBA). Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%.

	Model 1	Model 2	Model 3
Intercept	0.000 [0.087]	0.000 [0.082]	0.000 [0.082]
Lagged subprime fixed-rate mortgage delinquency rate	-0.184* [0.089]		-0.056 [0.087]
Chicago Board Options Exchange Volatility Index (CBOE VIX)		-0.419*** [0.082]	-0.401*** [0.087]
Adjusted R^2 (%)	2.59	16.84	16.44

Table 6: Descriptive Statistics of Subprime Mortgage Loan Credit and Prepayment Risk Variables Used in Our Sample

This table reports the descriptive statistics of individual loan characteristics of our subprime 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. White/caucasian is the omitted category for race.

Variable	Mean	Std Dev	5th Pctl	Median	95th Pctl
Original loan amount ($)	193,374	121,419	58,500	163,800	425,000
Loan-to-value ratio (LTV, %)	72.64	16.05	41	77	95
Combined LTV (%)	73.39	16.83	41	77	99
Borrower FICO score	577.74	37.41	512	583	618
Payment-to-income ratio	0.24	0.10	0.09	0.23	0.41
Full documentation	0.75	0.43	0	1	1
Low documentation	0.23	0.42	0	0	1
No documentation	0.01	0.12	0	0	0
Reduced documentation	0.01	0.11	0	0	0
Single family property	0.85	0.35	0	1	1
Planned-unit development (PUD)	0.07	0.25	0	0	1
Condominium	0.08	0.27	0	0	1
Cooperative	0.00	0.04	0	0	0
Home purchase	0.15	0.36	0	0	1
Rate/term refinance	0.21	0.41	0	0	1
Cash out refinance	0.64	0.48	0	1	1
Owner-occupied	0.96	0.20	1	1	1
Second/vacation home	0.00	0.06	0	0	0
Investment property	0.04	0.19	0	0	0
Without prepayment penalty	0.03	0.18	0	0	0
With prepayment penalty	0.64	0.48	0	1	1
Prepay penalty clause unknown	0.32	0.47	0	0	1
Race: Asian	0.02	0.15	0	0	0
Race: Black or African American	0.23	0.42	0	0	1
Race: other non-white	0.24	0.43	0	0	1
Female borrower	0.37	0.48	0	0	1
Census tract college graduate (%)	21.62	6.43	11.50	21.46	32.08
Originated by a large lenders (99^{th} percentile in origination volume)	0.25	0.44	0	0	1
Originated by a small lender (10^{th} percentile in origination volume)	0.18	0.39	0	0	1
N	86,926				

Table 7: Loan-level Mortgage Spread as Determined by Funding Liquidity and Credit Risk Variables

This table reports the OLS coefficient estimates from the loan-level subprime mortgage spread regression as it depends on our liquidity funding measures as well as credit and prepayment risk factors. All models include MSA-fixed effects, whose coefficients are not reported here. Continuous variables are standardized before running the regression. For CLTV, the reference group is "CLTV<80%"; for documentation types, the reference group is "full doc"; for collateral property type, the reference group is "Single-family"; the reference group for occupancy status is "owner-occupied"; for loan purpose, the reference group is "home purchase"; "with prepayment penalty" is the reference group for prepayment penalty type; "white" is the reference group for borrower race, "male borrower" is the reference group for gender, and "medium lender" is the reference group for lender type. Standard errors are reported in square brackets. ***, **, * and b for p<0.1%, p<1%, p<5%, and p<10%, respectively.

	Model 1	Model 2	Model 3	Model 4
Interest rate swap spread	0.182***		0.195***	0.141***
	[0.005]		[0.005]	[0.005]
Log subprime ABS issuance volume, 3-mo. MA	-0.075***		0.063***	0.033***
	[0.004]		[0.004]	[0.004]
Corporate bond credit spread		0.112***	0.157***	0.159***
		[0.005]	[0.005]	[0.005]
Lagged subprime FRM delinquency rate		0.121***	0.078***	0.067***
		[0.005]	[0.005]	[0.005]
Change in 10-year Treasury rate		0.162***	0.155***	0.157***
		[0.004]	[0.004]	[0.004]
FICO score (when below 540)				1.052***
				[0.066]
FICO score (when between 540 and 580)				1.509***
				[0.081]

FICO score (when between 580 and 620)				1.885***
				[0.088]
FICO score (when between 620 and 660)				-0.46***
				[0.021]
FICO score (when between 660and 720)				0.468***
				[0.02]
FICO score (when over 720)				0.284***
				[0.012]
Payment-to-income ratio (when below 23%)				0.061***
				[0.01]
Payment-to-income ratio (when between 23-31%)				0.135***
				[0.009]
Payment-to-income ratio (when it is over 31%)				0.211***
				[0.009]
Combined LTV between 80-90%				0.251***
				[0.01]
Combined LTV over 90%				0.16***
				[0.015]
Large loan (original balance > $417,000)				0.348***
				[0.018]
Low documentation loan				0.295***
				[0.01]
No documentation loan				0.298***
				[0.034]
Reduced documentation loan				0.482***
				[0.036]
Planned-unit development loan				0.168***
				[0.016]
Condominium loan				0.241***
				[0.015]

Cooperative loan				0.272**
				[0.093]
Rate/term refinance loan				0.002
				[0.015]
Cash out refinance loan				0.092***
				[0.013]
Second/vacation home loan				0.26***
				[0.071]
Investment property loan				0.697***
				[0.022]
With prepayment penalty				0.257***
				[0.023]
Prepayment penalty clause unknown				0.281***
				[0.023]
Asian borrower				0.02
				[0.027]
African American borrower				0.151***
				[0.01]
Other non-white borrower				0.069***
				[0.01]
Female borrower				0.032***
				[0.008]
Percentage college graduate in the census tract				0.001
				[0.004]
Originated by a large lenders				0.107***
				[0.01]
Originated by a small lender				0.006
				[0.011]
Adjusted R^2 (%)	16.36	18.13	19.78	30.79

Table 8: Descriptive Statistics of the Time-Varying Covariates in the Loan Performance Sample

This table reports descriptive statistics of time-varying covariates of the loan performance sample that are used in the default hazard model. Negative equity is the percentage difference between the market value of the loan and the market value of the property loan, where the contemporaneous market value of the property is calculated based on property value at origination plus change therein as indicated by a local Case-Shiller house price index (HPI). Volatility adjusted negative equity is the negative equity divided by HPI volatility. Refinance incentive is measured by the percentage difference between the loan's estimated market value and its stated book value. ABS issuance and the swap spread are lagged one month.

	Mean	STD	5th Pctl.	Median	95th Pctl.
Volatility adjusted negative equity (Leverage-Solvency Risk)	0.091	0.799	-1.018	0.297	0.565
Refinance incentive (Prepayment-driven Credit Risk)	0.058	0.094	-0.063	0.035	0.237
Change in MSA unemployment rate from loan origination to the current (%) (Borrower Liquidity Risk)	0.017	0.970	-1.167	-0.354	1.945
Lagged subprime ABS issuance (in log) (Sector Funding Liquidity)	6.248	5.130	0.000	10.009	11.410
Lagged swap spread (%) (Macro Funding Liquidity)	0.414	0.228	0.027	0.460	0.687
Number of events (loan-quarters)	2,039,962				

Table 9: Subprime Mortgage Spread and Realized Credit Performance

This table reports the maximum likelihood coefficient estimates (MLE) of the default hazard model, showing the relation between subprime mortgage default outcomes and loan origination mortgage spread. Default is defined as over 60-day delinquent. Spread$^{\perp}$ is the orthogonalized spread, which is the residual of regression where mortgage spread is regressed on our funding

liquidity measures. Loan origination year and current year fixed effects are included. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

	Model 1	Model 2
Spread	0.144***	
	[0.004]	
Square term of spread	-0.002	
	[0.002]	
Spread⊥		0.127***
		[0.004]
Square term of spread⊥		0.002
		[0.002]
Origination year-fixed effect	Yes	Yes
Current year-fixed effect	Yes	Yes
-2LogL	1,688,602	1686,387
A.I.C.	1,688,644	1686,442

Table 10: The Baseline Subprime Mortgage Loan Performance Model

This table reports the maximum likelihood coefficient estimates (MLE) of the baseline default hazard model, showing the relation between credit performance and credit risk factors. Default is defined as over 60-day delinquency. The model is estimated based on the loan performance data of our sample subprime loans. MSA-fixed effects, origination year-fixed effects and current year-fixed effects adjusted for current negative equity to account for time-varying solvency risks are included but coefficient estimates are not reported. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

	Model 1
FICO score (when below 540)	-0.673***

	(0.058)
FICO score (when between 540 and 580)	-0.868***
	(0.068)
FICO score (when between 580 and 620)	-1.019***
	(0.074)
FICO score (when between 620 and 660)	-0.065***
	(0.012)
FICO score (when between 660and 720)	-0.059***
	(0.011)
FICO score (when over 720)	-0.039***
	(0.006)
Payment-to-income ratio (when below 23%)	0.056***
	(0.009)
Payment-to-income ratio (when between 23-31%)	0.086***
	(0.009)
Payment-to-income ratio (when it is over 31%)	0.108***
	(0.008)
Combined LTV between 80-90%	0.122***
	(0.01)
Combined LTV over 90%	0.234***
	(0.013)
Large loan (original balance > $417,000)	0.060***
	(0.017)
Low doc loan	0.161***
	(0.009)
No doc loan	0.091**
	(0.029)
Reduced doc loan	0.037
	(0.028)
Planned-unit development loan	-0.063***
	(0.015)
Condominium loan	-0.050**
	(0.015)
Cooperative loan	-0.010
	(0.115)

Rate/term refinance loan	-0.280***
	(0.013)
Cash out refinance loan	0.003
	(0.012)
Second/vacation home loan	0.099
	(0.066)
Investment property loan	0.140***
	(0.020)
With prepayment penalty	-0.019
	(0.021)
Prepayment penalty clause unknown	-0.037
	(0.021)
Asian borrower	-0.030
	(0.027)
African American borrower	0.045***
	(0.009)
Other non-white borrower	0.015
	(0.009)
Female borrower	-0.018*
	(0.008)
Percentage of college graduate in the census tract	0.003
	(0.004)
Originated by a large lenders	0.021*
	(0.009)
Originated by a small lender	-0.009
	(0.010)
Cumulative change in MSA unemployment rate (%)	0.084***
	(0.008)
Volatility adjusted negative equity	0.204***
	(0.046)
Square term of volatility-adjusted negative equity	0.001***
	(0.000)
Refinance incentive * prepayment penalty effective	0.060***
	(0.005)
Refinance incentive * prepayment penalty expired	-0.004

	(0.003)
MSA-fixed effect	Yes
Origination year-fixed effect	Yes
Negative equity-adjusted current year-fixed effect	Yes
-2LogL	1,680,372
A.I.C.	1,680,512

Table 11: Subprime Mortgage Loan Performance as Determined by Credit Risk Factors and Liquidity Variables

This Table shows the relation between default hazard rate and contemporaneous liquidity variables and liquidity variables at loan origination. Default is defined as over 60-day delinquency. The model is estimated based on the loan performance data in our sample of subprime loans. MSA-fixed effects and origination year-fixed effects adjusted for current negative equity to account for time-varying solvency risks are included but coefficient estimates are not reported. Control variables include all those in Table 10. Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

	Model 2	Model 4	Model 2 with data only up to 2008	Model 4 with data only up to 2008
Lagged subprime ABS issuance (in log)	-0.113***	-0.112***	-0.095***	-0.095***
	[0.008]	[0.008]	[0.011]	[0.011]
Lagged swap spread (%)	0.121***	0.121***	0.190***	0.188***
	[0.008]	[0.008]	[0.014]	[0.014]
Log subprime ABS issuance volume at loan origination, 3-month MA		0.033***		0.013*
		[0.009]		[0.006]
Interest rate swap spread at loan origination		0.058***		0.057***

		[0.012]		[0.016]
All controls in Table 10	Yes	Yes	Yes	Yes
-2LogL	1,679,909	1,679,880	815,216	815,204
A.I.C.	1,680,053	1,680,028	815,348	815,340

Table 12: Differential Impacts of Sector Funding Liquidity on Large- versus Small-remaining Balance Loans

This table shows MLE coefficient estimates of the default hazard model that includes an interaction between lagged subprime ABS issuance and a remaining loan size (jumbo size) indicator. It demonstrates the effect of liquidity-driven default, since jumbo size loans are more affected by funding illiquidity in the subprime mortgage market. Control variables include all those in Table 11, Model 2. Standard errors are in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

	Model 3
Lagged subprime ABS issuance (in log)	-0.043*** [0.007]
Lagged subprime ABS issuance (in log) * jumbo remaining balance	-0.108*** [0.016]
All controls in Table 11, Model 2	Yes

Table 13: Relation between Sector Funding Liquidity and Credit Risk, 2006-2008

This table reports monthly subprime ABS issuance volume (in log) regressed on lagged subprime fixed- rate mortgage delinquency rate and CBOE VIX. Data are from January 2006 to May 2008. Subprime ABS issuance volume is from ABAlert, and subprime mortgage delinquency rate is from the Mortgage Bankers Association (MBA). Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%.

	Model 1	Model 2
Intercept	0.644* [0.276]	1.561** [0.502]
Lagged subprime fixed-rate mortgage delinquency rate	-1.159*** [0.268]	-1.820*** [0.400]
Chicago Board Options Exchange Volatility Index (CBOE VIX)		1.028* [0.482]
Adjusted R^2 (%)	39.55	46.79

Appendix Table 1: Sample Subprime Mortgage Loan Pricing Menu

Full doc	FICO	LTV	Backend	Mortgage interest rate
	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	

Notes: 1) These are 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.

Appendix Table 2: 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 subprime mortgage spread regressed on similarly calculated changes in interest rate swap spread, 3-month moving average subprime ABS issuance volume, corporate credit spread, lagged subprime fixed- rate mortgage delinquency rate, and 10-year Treasury bond rate. Aggregate subprime mortgage spread is the weighted average (weighted by origination loan amount) subprime mortgage spread in each month. Subprime ABS issuance volume is from ABAlert, and subprime mortgage delinquency rate is from the Mortgage Bankers Association (MBA). Standard errors are reported in square brackets. ***, **, and * for p<0.1%, p<1%, and p<5%, respectively.

	Δ Spread over Treasury rate		
	Model 1	Model 2	Model 3
Intercept	0.207* [0.080]	0.214* [0.083]	0.214** [0.074]
Δ Interest rate swap spread	0.252** [0.081]		0.301*** [0.077]
Δ Log subprime ABS issuance volume, three months moving average	-0.331** [0.081]		-0.215*** [0.081]
Δ Corporate bond credit spread		0.028 [0.088]	0.018 [0.080]
Δ Lagged subprime fixed-rate mortgage delinquency rate		0.318*** [0.089]	0.283** [0.084]
Δ 10-year Treasury rate		-0.181* [0.084]	-0.175* [0.075]
Adjusted R^2 (%)	20.48	15.28	31.63