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Staff Reports

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Andreas Fuster
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Staff Report No. 674
May 2014



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Understanding Mortgage Spreads

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Abstract

Spreads of agency mortgage-backed securities (MBS) vary significantly in the cross section and over time, but the sources of this variation are not well understood. We document that, in the cross section, MBS spreads adjusted for the prepayment option show a pronounced smile with respect to the MBS coupon. We propose prepayment model risk as a candidate driver of MBS spreads and present a new pricing model that uses “stripped” MBS prices to identify the contribution of this risk to option-adjusted spreads. With this pricing model, we find that prepayment model risk explains the smile, while the variation in the time series is mostly accounted for by a non-prepayment-risk component, which is related to credit risk in fixed-income markets and MBS supply. Finally, we study the MBS market response to the Fed’s large-scale asset purchases and show that the model is consistent with spread movements following the initial announcement and, in particular, the fanning out of option-adjusted spreads across different coupons.

Key words: agency mortgage-backed securities, option-adjusted spreads, prepayment model risk, OAS smile

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1 Introduction

With about \$6 trillion in principal outstanding, residential mortgage-backed securities (MBS) guaranteed by US government-sponsored enterprises Fannie Mae and Freddie Mac and the government agency Ginnie Mae are among the world's most important fixed income assets.¹ Timely repayment of principal and interest in these securities is, either explicitly or implicitly, backed by the US government. Nevertheless, MBS spreads to Treasuries or plain-vanilla interest rate swaps, often called the "mortgage basis," vary significantly over time and across mortgage securities. To some extent the mortgage basis reflects compensation for interest rate risk from the prepayment option embedded in an MBS, which allows borrowers to prepay their mortgage balance at any time. But even after accounting for interest rate variability and predicted prepayments, the resulting option-adjusted spreads (OAS) can reach high levels. Furthermore, we document a marked U-shaped pattern of OAS across coupons in the cross section, which we refer to as the "OAS smile." Beyond its asset pricing significance, variation in the mortgage basis is also of key macroeconomic importance because of the central role played by MBS in funding US housing. Reflecting this importance, a spike in the mortgage basis in the fall of 2008 contributed to the Federal Reserve's decision to embark on unconventional monetary policies through large-scale MBS purchases.

What are the key risk factors that drive variation in the mortgage basis, and how can we tell them apart? In a simple theoretical framework, we show that MBS investors face prepayment model risk, which is the risk of over- or underpredicting future prepayments for given interest rates.² The main contribution of this paper is to propose and implement a new method that uses market prices to identify this risk, which is unaccounted for in standard MBS pricing models. We find that prepayment model risk premia explain the OAS smile, while the variation in average OAS over time is mostly explained by a non-prepayment risk component, which is related to credit risk spreads and MBS supply. We use this decomposition to study the fanning out (divergence) of OAS across coupons in response to the Fed's November 2008 MBS purchase announcement and discuss related policy implications.

¹The outstanding amount is from SIFMA as of 2013:Q4. The term "MBS" in this paper refers only to securities issued by Freddie Mac and Fannie Mae or guaranteed by Ginnie Mae and backed by residential properties; there are also "private-label" residential MBS issued by private firms (and backed by subprime, Alt-A, or jumbo loans), as well as commercial MBS. Only Ginnie Mae securities are explicitly guaranteed by the full faith and credit of the US government, while Freddie Mac and Fannie Mae securities have an effective, or implicit, guarantee.

²Previous studies (for example, [Goldman Sachs, 1995](#); [Levin and Davidson, 2005](#); [Gabaix, Krishnamurthy, and Vigneron, 2007](#)) have also highlighted the role of this risk.

We characterize MBS spreads adjusted for the prepayment option (or OAS) on the universe of outstanding securities over a period of 15 years and using (for robustness) quotes from six different dealers. In the time series, we find OAS on a market value-weighted index to be typically close to zero, consistent with the limited credit risk of MBS. However, OAS reach high levels in periods of market stress, such as 1998 (around the failure of LTCM) or the fall of 2008. We document variation in the cross section of MBS as a function of their coupon or, more precisely, their moneyness—the difference between the note rate on the loans underlying an MBS and the mortgage rate on newly originated loans—which is a key feature that distinguishes one MBS from another. In this cross section, we uncover an “OAS smile,” meaning that spreads tend to be lowest for securities for which the prepayment option is at-the-money (ATM), and increase if the option moves out-of-the-money (OTM) or in-the-money (ITM).

The OAS smile suggests that investors in ITM and OTM securities require additional risk compensation, and we discuss possible sources of this additional risk premium using a simple conceptual framework. One possibility is that newly issued MBS, which trade close to par, may require a lower OAS due to better liquidity, since they are more heavily traded. The results of our pricing model and decomposition are, however, inconsistent with this explanation. Instead we show that the OAS smile can be explained by prepayment model risk. This risk arises because MBS prepayment rates vary not only with interest rates but also with other systematic factors (γ_t) such as house prices, underwriting standards, or government policies. The standard OAS is computed accounting for rate uncertainty but holding γ_t fixed; thus the OAS will be contaminated by compensation for these risks. To correctly account for this additional risk, we use market prices to extract risk-neutral prepayment rates.

Prices of standard MBS (or pass-throughs) are insufficient to isolate prepayment model risk premia in the OAS, because a single price observation only pins down the total OAS. We propose a method that circumvents this identification issue by using prices of paired “stripped” MBS—an interest-only (IO) and a principal-only (PO) strip—which value interest payments separately from principal accruals on a given MBS. We show that this additional pricing information, and the assumption that a pair of strips is priced fairly, can identify market-implied risk-neutral (“Q”) prepayment rates as multiples of physical (“P”) ones. We then obtain the prepayment model risk premium component in the OAS as the difference between the OAS computed using physical (OAS^P) and risk-neutral prepayments (OAS^Q).

We find that the OAS smile is explained by higher prepayment model risk for securities that

are OTM and, especially, ITM. There is little evidence that liquidity or other risks vary significantly with moneyness, except perhaps for the most deeply ITM securities. In the time series, we find that much of the OAS variation on the value-weighted index is driven by the OAS^Q component. We document that average OAS^Q are related to spreads on other agency debt securities, which may reflect common risk factors such as changes in the implicit government guarantee. In particular, both spreads spiked in the fall of 2008, when Fannie Mae and Freddie Mac were placed in conservatorship by the US Treasury. However, spreads on MBS and agency debt also tend to co-move earlier in the sample, possibly pointing to other common factors such as liquidity. OAS are also linked to credit spreads (Baa-Aaa), suggesting common pricing factors in the two markets. One possible such factor that has been highlighted in the literature is limited risk bearing capacity of financial intermediaries. Consistently, we find that the supply of MBS, measured by issuance relative to mark-to-market equity of brokers and dealers, is a significant determinant of OAS^Q . The response of OAS to LSAPs provide further evidence on this channel. In particular, OAS^Q narrowed across coupons as the Fed reduced the outstanding stock of MBS available to private investors through the purchase program.

Our pricing model consists of a prepayment and an interest rate component. The interest rate component is a three-factor [Heath et al. \(1992\)](#) model calibrated to the term structure of swap rates and the interest rate volatility surface implied by the swaption matrix using a minimum distance estimator. To capture market participants' expectations and to be consistent with their pricing and spreads, we extract the parameters of our physical prepayment model from a survey of dealer models' long-run prepayment projections from Bloomberg LP.

While much of the discussion in the paper centers on OAS, we also discuss unadjusted spreads and the option cost, as measured by the difference between the OAS and unadjusted spreads. We uncover a cross-sectional hump-shaped pattern in the option cost, which we explain with differential sensitivity to interest rate volatility (or Vega) across securities with different moneyness levels. In the time series, option cost variation is explained by changes in implied rate volatility.

The rest of the paper is organized as follows. After relating our work to the existing literature, in [Section 2](#) we provide a brief overview of the MBS market, define the spread measures, and then characterize their variation including the OAS smile. [Section 3](#) presents a simple conceptual framework to discuss possible sources of spread variation. We propose a method to isolate compensation for prepayment model risk from other risk premia in [Section 4](#), and implement this method using a new pricing model. [Section 5](#) discusses results of this model including the spread

response following the announcement of the first round of large-scale MBS purchases by the Federal Reserve in 2008. We draw policy implications of this analysis in the paper's conclusion.

1.1 Related literature

This paper is connected to several strands of literature. First, we show that, consistent with the theory of limited risk-bearing capacity of intermediaries (such as [Shleifer and Vishny, 1997](#); [Duffie, 2010](#); [He and Krishnamurthy, 2013](#); [Brunnermeier and Sannikov, 2014](#)), investors in the MBS market earn a higher risk premium when intermediaries face greater capacity constraints. In particular, when the supply of MBS securities is large relative to intermediaries' equity, the liquidity risk premium in this market increases. Thus, similar to the findings of [Adrian et al. \(2013\)](#) for equity and bond portfolios, measures of intermediary risk bearing capacity are a priced risk factor in the time series. In this environment, the LSAP program relaxed intermediary capacity constraints and thus improved the overall liquidity in the MBS market. At the same time, the program had a countervailing effect by lowering mortgage rates and increasing prepayment risk premia. This leads the net impact of LSAPs on high coupons (which represent the majority of outstanding MBS) to be small, thereby limiting the recapitalization effect of monetary policy described in [Brunnermeier and Sannikov \(2012\)](#). The countervailing effects of LSAPs on OAS are also distinct from the effects highlighted in previous studies (such as [Gagnon et al., 2011](#); [Greenwood and Vayanos, 2014](#); [Krishnamurthy and Vissing-Jorgensen, 2013](#)), as we discuss in the paper's conclusion.

[Grossman and Zhou \(1996\)](#) proposed that the limited arbitrage capital of portfolio insurers can lead out-of-the-money equity options to trade at a higher volatility than in-the-money ones. In contrast, we find that, while the risk-bearing capacity of intermediaries does influence the average level of the OAS, it is not the source of the OAS smile. The OAS smile is connected more generally to the literature studying the volatility smile in equity options. [Buraschi and Jackwerth \(2001\)](#) point out that additional (beyond the evolution of the underlying) priced risk factors, such as stochastic volatility and interest rates, are needed to explain the post-1987 smile in the volatility surface. We similarly find that the OAS smile can be explained by allowing priced variation in the parameters of the prepayment model. Our paper also shares the option pricing view (see e.g. [Jackwerth and Rubinstein, 1996](#); [Pan, 2002](#); [Eraker, 2004](#); [Broadie et al., 2007](#)) that any potential explanation of the smile should be confronted with data drawn from both the historical and the risk-neutral distribution.

From a methodological perspective, this paper is also related to credit risk studies that con-

front their models with both physical and risk-neutral (that is, pricing) data to evaluate default risk premia. [Driessen \(2005\)](#), for example, uses US bond price data and historical default rates to estimate a default event risk premium. [Driessen](#) parameterizes the risk-neutral intensity of default as a multiple of the historical intensity; in this paper, we follow a similar approach in parametrizing the risk-neutral prepayment path as a multiple of the prepayment path under the historical measure. [Almeida and Philippon \(2007\)](#) use the default risk premia estimated for bonds with different credit rating to compute the risk-adjusted costs of financial distress for firms in the same ratings class. Our exercise is similar in spirit in that we use the prepayment risk premia estimated for different MBS pools to compute prepayment risk-adjusted liquidity costs faced by investors in this market.

A number of papers have studied the interaction of interest rate risk in MBS and other markets. In these models, investors' need to hedge MBS convexity risk may explain significant variation in interest rate volatility and excess returns on Treasuries ([Duarte, 2008](#); [Hanson, 2014](#); [Malkhozov et al., 2013](#); [Perli and Sack, 2003](#)). Our analysis is complementary to this work as we focus on MBS specific risks as well as how they respond to changes in other fixed income markets. More closely related to this paper, [Boudoukh et al. \(1997\)](#) suggest that prepayment-related risks are a likely candidate to account for the component of TBA prices not explained by the variation in interest rate level and slope. [Carlin et al. \(2014\)](#) use long-run prepayment projections to study the role of disagreement in MBS returns and their volatility. Perhaps closest to our work, [Gabaix et al. \(2007\)](#) study OAS on IO strips from a dealer model between 1993 and 1998, and document that these OAS covary with the moneyness of the market, a fact that they show to be consistent with a prepayment risk premium and the existence of specialized MBS investors. [Gabaix et al.](#) do not focus on pass-through MBS and, while their model successfully explains the OAS patterns of the IOs in their sample, it predicts a linear rather than a smile-shaped relation between a pass-through MBS's OAS and its moneyness, since they assume that securities have a constant loading on a single-factor aggregate prepayment shock. We consider liquidity as an additional risk factor in the OAS and also show that the OAS smile is in fact a result of prepayment model risk but of a more general form than what [Gabaix et al.](#) assume. In a similar manner to this paper's empirical pricing model, [Levin and Davidson \(2005\)](#) extract a market-implied prepayment function from the cross section of TBA securities.³ Because they assume, however, that the residual risk premia in

³[Arcidiacono et al. \(2013\)](#) extend their method to more complex CMOs. [Cheyette \(1996\)](#) and [Cohler et al. \(1997\)](#) are earlier practitioner papers proposing that MBS prices can be used to obtain market-implied prepayments.

the OAS are constant across coupons, the OAS smile is implicitly assumed to be explained only in terms of prepayment model risk. By using additional information from stripped MBS, the method in this paper instead relaxes this assumption.

2 Facts about mortgage spreads

In this section we first provide a brief overview of MBS and their spread measures. We then characterize the time series and cross-sectional spread variation in terms of a few stylized facts.

2.1 The agency MBS market and spreads

In an agency securitization, a mortgage originator pools loans and then delivers the pool in exchange for an MBS certificate, which can subsequently be sold to investors in the secondary market.⁴ Servicers, which are often affiliated with the loan originator, collect payments from homeowners that are passed on to MBS holders after deducting a servicing fee and the agency guarantee fee. In the simplest form of MBS, known as a pass-through, homeowners' payments are assigned pro-rata to all investors. However, cash flow assignment rules can be more complicated with multiple tranches, as is the case for stripped MBS, which we will discuss in Section 4, and collateralized mortgage obligations (CMOs). We focus on MBS backed by fixed-rate mortgages (FRMs) with original maturity of 30 years on 1-4 family properties; these securities account for more than two-thirds of all agency MBS.⁵

In agency MBS, the risk of default of the underlying mortgages is not borne by investors but by the agencies that guarantee timely repayment of principal and interest. Because of this guarantee, agency MBS are generally perceived as being free of credit risk. However, while Ginnie Mae securities have the full faith and credit of the US federal government, assessing the credit risk of Fannie Mae and Freddie Mac securities is more complex. Indeed, government backing for these securities is only implicit and results from investors' anticipation of government support under a severe stress scenario, as was the case in the fall of 2008.

Beyond the implicit guarantee, a distinct feature of MBS is the embedded prepayment option: borrowers can prepay their loan balance at par at any time, without paying a fee. Because borrowers are more likely to do so when rates decline, MBS investors are exposed to reinvestment risk

⁴In addition to these "lender swap transactions," Fannie Mae and Freddie Mac also conduct "whole loan conduit" transactions, where they buy loans against cash from (typically smaller) originators, pool these loans themselves, and then market the issued MBS.

⁵As of March 2014, the balance-weighted share is 69 percent (author calculations based on data from eMBS).

and have limited upside as rates decline, or more formally, they are short an American option. The embedded prepayment option is crucial in the valuation of MBS, since it creates uncertainty in the timing of future cash flows, X_t . As discussed in more detail in Section 4.3, prepayment rates depend on loan characteristics as well as macroeconomic factors such as interest rates and house prices. While uncertainty about all of these factors (and their impact on prepayments) affects the value of the embedded option, only interest rate uncertainty is explicitly accounted for in computing spreads, a fact that we highlight by denoting cash-flow dependence on interest rates by $X_t(r_t)$.⁶

MBS valuations are usually assessed based on option-adjusted spreads (OAS) or zero-volatility spreads (ZVS, also called Z-spreads). Denoting by P_M the market price of an MBS, these spreads are defined by

$$OAS : P_M = \mathbb{E} \sum_{k=1}^T \frac{X_k(r_k)}{\prod_{j=1}^k (1 + OAS + r_j)}, \quad (2.1)$$

$$ZVS : P_M = \sum_{k=1}^T \frac{X_k(\mathbb{E}r_k)}{\prod_{j=1}^k (1 + ZVS + \mathbb{E}r_j)}. \quad (2.2)$$

Thus, the OAS is the constant spread to baseline rates that sets the discounted value of cash flows equal to its market price. In practice, the expectation term in the OAS calculation is computed with Monte Carlo simulations using a term structure model calibrated to interest rate options, and then obtaining cash flows via a prepayment function that depends on rates. In computing the ZVS, instead, both cash flows and discounts are evaluated along a single expected risk-neutral rate path, thus ignoring the effects of uncertainty about the timing of prepayments on the MBS valuation. This implies that the ZVS will be larger than the OAS.⁷ More generally, both the ZVS and OAS increase the larger the value of discounted cash flows (that is, the model-implied price) relative to the market price, meaning that when spreads are positive, MBS trade below the model price. Because ZVS abstract from rate uncertainty, following practitioners (for

⁶Appendix A provides a detailed description of how MBS cash flows depend on prepayments and scheduled amortization.

⁷Market participants also sometimes consider simple yield spreads (YS). As for the ZVS, the YS computes cash flows abstracting from uncertainty but discounts at $((1 + YS + y^*)^t)$, where y^* is the swap rate with a duration that is closest (or equal by interpolating rates for the two rates with the closest duration) to the MBS duration. Unlike the ZVS, the YS discounts all cash flows at a constant rate y^* , which is independent of cash flow timing, and as a result, changes in the slope of the yield curve (or duration of the MBS) will not be reflected in the YS.

example, [Hayre, 2001](#)) we refer to the ZVS-OAS difference as the “option cost”:⁸

$$\text{Option cost} \equiv \text{ZVS} - \text{OAS}. \quad (2.3)$$

In the remainder of this section, we characterize the spread variation in the MBS universe using a market value-weighted index (in the time series) as well as in terms of MBS moneyness (in the cross section). We consider spreads relative to swaps, rather than Treasuries, since these instruments are more commonly used for hedging MBS (see e.g. the discussion in [Duarte, 2008](#)) and also because interest rate volatility measures, used to calibrate the term structure model, are more readily available for swaps.⁹ We use spreads in the to-be-announced (TBA) market, where the bulk of MBS trading happens. The TBA market is a forward market for pass-through MBS where a seller and buyer agree on a select number of characteristics of the securities to be delivered (issuer, maturity, coupon, par amount), a transaction price, and a settlement date either 1, 2, or 3 months in the future. The precise securities that are delivered are only announced 48 hours prior to settlement, and delivery occurs on a “cheapest-to-deliver” basis (see [Vickery and Wright, 2013](#), for a detailed discussion). Because spread measures are highly model-dependent, we collected end-of-month spread measures (ZVS and OAS, both relative to swaps) on Fannie Mae securities from six different dealers over the period 1996 to 2010.¹⁰ As a result, the stylized facts we present are robust to idiosyncratic modeling choices of any particular dealer and, through data-quality filters we impose, issues arising from incorrect or stale price quotes. Further details on the sample and data-quality filters are available in Appendix B.

2.2 Time series variation in spreads

The benchmark contract in the TBA market is the so-called current coupon, which is a synthetic par contract for a 30-year fixed rate MBS obtained from interpolating the highest coupon below par and the lowest coupon above par, or alternatively by extrapolating from that latter security in

⁸We note, however, that this is a slight misnomer, as adding volatility to discount rates (in the denominator of equation (2.1)) increases the model value and therefore raises OAS relative to ZVS. In practice, this countervailing effect is small, such that ZVS almost always exceed OAS.

⁹[Feldhütter and Lando \(2008\)](#) study the determinants of spreads between swaps and Treasuries and find that they are mostly driven by the convenience yield of Treasuries, though MBS hedging activity may also play a role at times.

¹⁰Freddie Mac securities are generally priced close to Fannie Mae’s, reflecting the similar collateral and implicit government backing. The prices and spreads of Ginnie Mae securities can differ significantly (for the same coupon) from Fannie and Freddie MBS, reflecting the difference in prepayment characteristics (Ginnie Mae MBS are backed by FHA/VA loans) and perhaps the explicit government guarantee. Throughout this paper, we focus on Fannie Mae MBS.

case no coupon is trading below par (which has frequently been the case in recent years).¹¹ The interest in this benchmark is due to the fact that most newly originated mortgages are securitized in coupons trading close to par, so that the current coupon rate can be thought of as the relevant secondary market rate for borrowers seeking a new loan.

Despite its benchmark status, the current coupon is not representative of the MBS universe as a whole, because at any point in time, only a relatively small fraction of the universe is in coupons trading close to par. This is illustrated in Figure 1. For example, the current coupon at the end of 2010 was around 4 percent (red line, measured on the right y-axis) but securities with a coupon of 4 percent accounted for only about 20 percent of the total outstanding on a market value-weighted basis. Another issue with the current coupon is that since it is a synthetic contract, variation in its yield or spreads can be noisy because of inter- and extrapolations from other contracts and the required assumptions about the characteristics of loans that would be delivered in a pool trading at 100 (see [Fuster et al., 2013](#), for more detail).

To characterize the time series variation in spreads, we therefore follow fixed income indices (such as Barclays and Citi, which are main benchmarks for money managers) and construct a market value-weighted index (the “TBA index”) using the universe of outstanding pass-through MBS. In contrast to other indices, however, we do not rely on any particular dealer’s pricing model; instead, we average the spread measure of interest (OAS or ZVS) for a coupon across the dealers for which we have quotes on a given day, and then compute averages across coupons using the market value of the remaining principal balance of each coupon in the MBS universe.

The resulting time series of spreads on the TBA index is shown in Figure 2. The mortgage basis as measured by the ZVS (grey line) is typically around 50 to 100 basis points, but rose above 200 basis points during the period of widespread financial stress in the fall of 2008. The mortgage basis also reached high levels around the 1998 LTCM turmoil, and in 2002 and 2003 in conjunction with the unprecedented refinancing wave in mortgage markets. Just like the unadjusted basis, the OAS (black line) reaches high levels in periods of market stress, but tends to be less volatile outside these periods. The chart also shows that the OAS on the value-weighted index is generally close to zero, consistent with the limited credit risk of MBS.

While we have not yet discussed potential drivers of MBS spreads, we now briefly study the relationship between spreads on the TBA index and fixed income risk factors. In particular, we

¹¹Sometimes the term “current coupon” is used for the actual coupon trading just above par; we prefer the term “production coupon” to refer to that security.

consider: (i) the convenience yield on Treasury securities (reflecting their liquidity and safety) as measured by the Aaa-Treasury spread; (ii) credit spreads as measured by the Baa-Aaa spread; (iii) the slope of the yield curve (measured by the yield difference between 10-year Treasury bonds and 3-month Treasury bills); and (iv) the swaption-implied volatility of interest rates.¹² Regression estimates are reported in Table 1, where all right-hand-side variables are standardized so that each coefficient estimate can be interpreted as the spread impact in basis points of a unit standard deviation increase.

The takeaways from the table are the following: First, average OAS are strongly related to credit spreads, both over the full sample and the pre-crisis period (ending in July 2007), and are largely unaffected by the other risk measures. This suggests that there are common pricing factors between the MBS and corporate bond markets.¹³ Second, implied rate volatility does not explain the OAS variation, consistent with the prediction that OAS should not reflect interest rate uncertainty as the OAS adjusts for it. Conversely, the average ZVS is strongly related to implied volatility. Intuitively, as with other American options, the value of the prepayment option increases in the volatility of the underlying. In Section 5, we return to the determinants of the time series variation in spreads, focusing on the relationship with mortgage-specific risk factors.

2.3 Cross-sectional patterns and the OAS smile

While spread variation in the TBA index is informative of the MBS market as a whole, it masks significant variation in the cross section of securities. A salient feature that distinguishes one MBS from another in the cross section is the monetary incentive to refinance of borrowers in the loan pool underlying a security. We refer to this incentive as a security’s “moneyness” and define it (for security j at time t) as

$$\text{Moneyness}_{j,t} = \text{Coupon}_j + 0.5 - \text{FRMrate}_t.$$

¹²As in Krishnamurthy and Vissing-Jorgensen (2012) the Aaa-Treasury spread is the difference between the Moody’s Seasoned Aaa corporate bond yield and the 20-year constant maturity Treasury (CMT) rate. The Baa rate is also from Moody’s, and bill rates and 10-year Treasury yields are CMTs as well. All rates were obtained from the H.15 release. Swaption quotes are basis point, or normal, volatility of 2-year into 10-year contracts, from JP Morgan.

¹³Brown (1999) relates the OAS to Treasuries of pass-through MBS over the period 1993–1997 to other risk premia and finds a significant correlation of OAS with spreads of corporate bonds to Treasuries. He interprets his findings as implying a correlation between the market prices of credit risk or liquidity risk on corporates and that of prepayment risk on MBS, but notes that it could also be driven by time variation in the liquidity premium on Treasuries.

We add 0.5 to the coupon rate because the mortgage note rates are typically around 50 basis points higher than the MBS coupon.¹⁴ When moneyness > 0 , a borrower can lower his monthly payment by refinancing the loan balance—the borrower’s prepayment option is “in-the-money” (ITM)—while moneyness < 0 means that refinancing (or selling the home and buying another home with a new mortgage of equal size) would increase the monthly mortgage payment—the borrower’s option is “out-of-the-money” (OTM). Aside from determining the refinancing propensity of a loan, moneyness also measures an investor’s gains or losses (in terms of coupon payments) if a mortgage underlying the security prepays (at par) and he reinvests the proceeds in a “typical” newly originated MBS (which will approximately have a coupon equal to the FRM rate at time t minus 50 basis points).

Figure 3 shows the (pooled) variation of spreads and prices as a function of security moneyness. First, and most importantly for this paper, OAS display a smile-shaped pattern (panel a): adjusted spreads are lowest for at-the-money (ATM) securities and increase moving away in either direction, especially ITM. OAS on deeply ITM securities on average exceed those on ATM securities by 50 basis points or more. Explaining the smile-shaped pattern in OAS is the focus of the next section, where we turn to a model that features prepayment model risk and liquidity risk as two potential drivers.

Next, panel (b) shows that ZVS are generally increasing in a contract’s moneyness, though the relation flattens out for ITM securities. Panel (c) shows that the option cost (the difference between ZVS and OAS) is hump-shaped, with securities that are closest to par having the largest option cost. The hump shape of the option cost can be understood by analogy to the Vega (sensitivity to changes in the volatility of the underlying) of vanilla call options, which is small for options that are deeply ITM or OTM but large for options near the money. Option execution in MBS are driven by an S-shaped prepayment function (rather than an exercise boundary) as discussed in more detail in Section 4.3 but the patterns are analogous.¹⁵ As shown more formally in the next section, this pattern is directly related to the well-known “negative convexity” (i.e., concavity) of MBS prices with respect to rates, shown in panel (d): as rates drop (the security’s moneyness increases), prices increase less than linearly, especially for near-the-money securities.

¹⁴The difference gets allocated to the agency guarantee fee as well as servicing fees (see Fuster et al., 2013, for details). We could alternatively use a security’s “weighted average coupon” (WAC) directly, but the WAC is not known exactly for the TBA securities studied in this section.

¹⁵Intuitively, prepayments are not sensitive to small changes in interest rates when the prepayment option is deeply ITM or OTM, so that adding volatility to future interest rates matters little for the expected value of the security; the same is not true for ATM securities.

Table 2 shows that the pattern shown in panel (a) of Figure 3 is qualitatively robust to controlling for month fixed effects (meaning that only cross-sectional variation is exploited) and to ending the sample before the onset of the financial crisis. Instead of imposing parametric restrictions, we simply regress OAS on 50-basis-point moneyness bins, with $[-0.25, 0.25)$ as the omitted category. Comparing columns (1) to (2) and (3) to (4), we see that the addition of month fixed effects matters little for the relative OAS in the cross section. The relative spreads of OTM coupons are robust to removing the financial crisis period from the sample, while for ITM coupons, the difference to ATM securities was somewhat smaller pre-crisis, but still statistically significant.

3 Conceptual framework

As discussed above, the OAS is the spread to the risk-neutral discount rate curve after accounting for rate uncertainty, which conceptually corresponds to the expected excess return on an MBS when interest rate risk is hedged.¹⁶ Consider a mortgage pool j with coupon rate c_j and remaining principal balance θ_{jt} at time t . The pool prepays with intensity s_{jt} , so that the principal balance evolves (in continuous time) as

$$d\theta_{jt} = -s_{jt}\theta_{jt}dt.$$

We assume that the prepayment rate s_{jt} is a function of the interest rate incentive $c_j - r$ and a vector of parameters $\gamma_t = (\gamma_{1t}, \gamma_{2t}, \dots, \gamma_{Nt})'$, which are uncertain and give rise to prepayment model risk. For simplicity, and because we focus on the OAS, which is already adjusted for interest rate uncertainty, we assume here that interest rates r are constant, though we briefly discuss the model with uncertain rates at the end of this section. The prepayment rate is then given by

$$s_{jt} = f(\gamma_t, c_j - r).$$

The parameters γ_t are time-varying, with normal innovations, so that

$$d\gamma_t = \mu_\gamma dt + \sigma_\gamma dZ_{\gamma t},$$

¹⁶Consistent with this interpretation, Breeden (1994) provides evidence that OAS do predict subsequent hedged returns. An alternative view, taken for instance by Kupiec and Kah (1999), is that OAS are caused by misspecification of the prepayment model relative to what the marginal investor believes. In that view, OAS are simply “noise” and have no asset pricing significance. While it is certainly true that spreads are heavily model dependent, the view that they are just noise is difficult to reconcile with some of the facts documented in the previous section.

where $Z_{\gamma t}$ is a standard Brownian motion vector. The other source of uncertainty in the model is the liquidity of the securities. We assume that, with intensity μ_t , the whole market experiences a liquidity event in which a pool j loses a fraction α_{jt} of its market value. Thus α_{jt} should be thought of as how well the security performs in a “bad” market, similar to [Acharya and Pedersen \(2005\)](#). Alternatively, α_{jt} could be interpreted as the price impact of a decline in the strength of the agency guarantee. Under no-arbitrage there exists a pricing kernel M_t such that the time t price of a future stream of cash flows X_{t+s} is

$$P_t = \mathbb{E}_t \left[\int_0^{+\infty} \frac{M_{t+s}}{M_t} X_{t+s} ds \right]. \quad (3.1)$$

Equation (3.1) is the continuous-time analog of (2.1), where instead of discounting by the risk-free rate, we discount using the pricing kernel. Let R_t be the return to holding a claim to the stream of cash flows X_t , which evolves as

$$dR_t \equiv \frac{dP_t}{P_t} + \frac{X_t}{P_t} dt.$$

The no-arbitrage restriction (3.1) implies that the expected return can be represented as

$$\mathbb{E}_t [dR_t] = r dt - \mathbb{E}_t \left[\frac{dM_t}{M_t} \frac{dP_t}{P_t} \right],$$

where r is the risk-free rate. Comparing the above expression to the definition of the OAS in (2.1), to a first-order approximation, the OAS is the risk premium paid to an investor for holding the claim to X :

$$OAS_t \approx rp_t \equiv -\mathbb{E}_t \left[\frac{dM_t}{M_t} \frac{dP_t}{P_t} \right].$$

To solve for the OAS, denote by $\pi_{\gamma t}$ the vector of prices of risks associated with innovations to the prepayment model parameters, and π_{lt} the price of risk associated with the liquidity shock. In terms of the pricing kernel, these risk prices are given by the co-variation between the innovations to the pricing kernel and the shocks:

$$\pi_{\gamma t} = \left\langle dZ_{\gamma t}, \frac{dM_t}{M_t} \right\rangle; \quad \pi_{lt} = \left\langle dJ_t, \frac{dM_t}{M_t} \right\rangle,$$

where J_t is the Poisson process governing the liquidity shocks to the pool. For an investor holding a portfolio of MBS securities, this liquidity risk is undiversifiable, which implies (see e.g. [Driessen, 2005](#)) that $\pi_{lt} > 1$. We show in [Appendix C](#) that the OAS is given by

$$\begin{aligned} OAS_{jt} &= \alpha_{jt} \mu_t (\pi_{lt} - 1) - \pi'_{\gamma t} \sigma_\gamma \frac{1}{P_{jt}} \frac{\partial P_{jt}}{\partial \gamma_t} \\ &= \alpha_{jt} \mu_t (\pi_{lt} - 1) + \pi'_{\gamma t} \sigma_\gamma \frac{c_j - r}{(s_{jt} + c_j)(s_{jt} + r)} \frac{\partial s_{jt}}{\partial \gamma_t}, \end{aligned} \quad (3.2)$$

where the second line follows from the price of the pass-through in the no-uncertainty case:

$$P_{jt} = 1 + \frac{c_j - r}{r + s_{jt}}. \quad (3.3)$$

Expression (3.3) implies that security j trades at a premium ($P_{jt} > 1$) if $c_j - r > 0$ and at a discount ($P_{jt} < 1$) if $c_j - r < 0$. It also shows that premium securities suffer from an increase in the prepayment speed s_{jt} , while discount securities benefit from faster prepayments.

Based on (3.2), differences in OAS across securities could be the result of (i) differential exposure α_j to the liquidity shock, or (ii) differential price sensitivity to the prepayment parameters, that is, differential exposure to prepayment model risk. To understand the conditions under which prepayment model risk generates an OAS smile, we now study three stylized prepayment functions. In each case, \bar{s}_j corresponds to the expected prepayment speed on security j .

Case 1: $s_{jt} = \bar{s}_j + \gamma_{1t} \beta_j$. This is essentially the framework studied by [Gabaix et al. \(2007\)](#). Each pool has a constant exposure β_j to a single market-wide prepayment shock γ_1 . This leads OAS_{jt} in (3.2) to be linear in moneyiness $c_j - r$ (regardless of the sign of the risk price $\pi_{\gamma_{1t}}$), and is therefore inconsistent with the OAS smile.

Case 2: $s_{jt} = \bar{s}_j + \gamma_{1t}(c_j - r)$. Like the previous case, this specification features a single-factor prepayment shock structure, but a security's exposure now depends on its moneyiness: when ITM securities prepay faster than expected ($\gamma_1 > 0$), OTM securities prepay slower than expected. Such a pattern could arise for instance as a result of mortgage originators' capacity constraints during (larger than expected) refinancing waves.¹⁷ It is easy to see from (3.2) that this case would lead the

¹⁷When capacity is tight, mortgage originators may be less willing to originate purchase loans (which are more labor intensive), and they may reduce marketing effort targeted at OTM borrowers (for instance, to induce them to cash out home equity by refinancing their loan). [Fuster et al. \(2013\)](#) show that originators' profit margins are strongly correlated with mortgage application volume, consistent with the presence of capacity constraints.

OAS to be quadratic in $c_j - r$ (the risk price $\pi_{\gamma_{1t}}$ is positive in this case, since every security has a positive exposure to γ_1), and therefore could rationalize the OAS smile.

Case 3: $s_{jt} = \bar{s}_j + \gamma_{1t}\mathbf{1}_{c_j < r} + \gamma_{2t}\mathbf{1}_{c_j \geq r}$. In this multi-factor formulation, OTM and ITM prepayments are driven by different shocks (which for simplicity we assume to be orthogonal). For instance, γ_{1t} might represent the pace of housing turnover while γ_{2t} might be the effective cost of mortgage refinancing (which varies with underwriting standards and market competitiveness). In equilibrium, the signs of the prices of risk are determined by the average exposure of the representative investor. Holding a portfolio of ITM and OTM securities, this investor will have a negative exposure to γ_{1t} risk (since OTM securities benefit from fast prepayment) and a positive exposure to γ_{2t} risk (since ITM securities suffer from fast prepayment). Thus $\pi_{\gamma_{1,t}} < 0$ and $\pi_{\gamma_{2,t}} > 0$, resulting in a positive OAS for both ITM and OTM securities and a (v-shaped) OAS smile.

In sum, both a single-factor (case 2) or a multi-factor prepayment function (case 3) could lead to an OAS smile. Beyond the stylized prepayment functions studied here, prepayment model risk premia can explain the OAS smile whenever OTM securities are not a hedge for ITM pools (as they would be in case 1).¹⁸ However, as shown by the first term in equation (3.2), the OAS smile could also result from differential exposure α to liquidity risk. For instance, newly issued MBS (which are ATM) trade more often than older ones, potentially leading to a lower α and an OAS smile pattern. To separate liquidity and prepayment model risk premia, in the next section we provide a method to identify a “prepayment-model-risk-neutral OAS,” denoted OAS^Q , as the spread that only reflects liquidity risk:

$$OAS_{jt}^Q = \alpha_{jt}\mu_t (\pi_{lt} - 1).$$

The prepayment model risk premium paid to the investor is then just the difference between the OAS and OAS^Q and will only reflect prepayment model risk.

We conclude this section by briefly discussing a more general version of the model that features interest rate uncertainty to discuss the cross-sectional variation in the option cost. As discussed in Section 2, the option cost is reflected in the difference between the ZVS and the OAS, which with

¹⁸This is also pointed out by [Levin and Davidson \(2005\)](#), who note that “[a] single-dimensional risk analysis would allow for hedging prepayment risk by combining premium MBS and discount MBS, a strategy any experienced trader knows would fail.”

interest rate uncertainty can be shown to equal

$$ZVS_t - OAS_t = -\frac{1}{P_t} \frac{\partial^2 P_t}{\partial r_t^2} \frac{\sigma_r^2}{2},$$

where σ_r is the volatility in the innovation in the interest rate diffusion. According to this expression, the option cost is positive for negatively convex securities and is proportional to the Gamma of the security ($\partial^2 P_t / \partial r_t^2$). Based on standard results in option pricing, Gamma is generally greatest for at-the-money options and diminishes when moving either in or out of the money; furthermore, the option Vega, that is, its sensitivity to volatility, is directly related to its Gamma. This is consistent with the patterns shown in panels (c) and (d) of Figure 3: option costs are largest for ATM securities and prices are a concave function of moneyness (and therefore r).

4 Pricing model: Decomposing the OAS

In this section, we propose a method to decompose the “standard” OAS (or OAS^P) into a prepayment model risk component and a remaining risk premium (OAS^Q). We then implement this method using our own pricing model, consisting of an interest rate and a prepayment component. In contrast to standard approaches, such as Stanton (1995) or practitioner models, we will use information from stripped MBS to identify a market-implied prepayment function and the contribution of prepayment model risk to the OAS.

4.1 Identification of OAS^Q

As discussed in the previous section, the OAS only accounts for interest rate uncertainty (and only interest rates are simulated in empirical pricing models) but other sources of prepayment uncertainty are assumed constant in the OAS calculation. As a result, risk premia attached to these factors’ innovations contaminate the OAS. In this section we propose a method to identify a risk-neutral prepayment function, where the parameters are obtained from market prices, then compute an OAS using this function (OAS^Q) and finally obtain the contribution of prepayment model risk to the OAS.

Following the credit risk literature (e.g. Driessen, 2005), we assume that the market-implied risk-neutral (“Q”) prepayment function is a multiple Λ of the physical (“P”) one. We allow the multiplier Λ to be pool-specific to account for differences in pools’ sensitivities to non-interest rate sources of prepayment uncertainty. Pricing information on a standard pass-through MBS alone is

insufficient to identify Λ , because a single observable (the price) can only determine one unknown (the spread) in the pricing model, leaving Λ unidentified.

To resolve this identification problem, we use additional pricing information from “stripped” MBS, which separate cash flows from pass-through securities into an interest component (“interest only” or IO strip) and a principal component (“principal only” or PO strip). Cash flows of these strips depend on the same underlying prepayment path and therefore face the same prepayment uncertainty, but are exposed to it in opposite ways, as illustrated in Figure 4. As prepayment rates increase (top to bottom panel), total interest payments shrink (since interest payments accrue only as long as the principal is outstanding) and thus the value of the IO strip declines. Conversely, principal cash flows experience early accrual (sum of grey areas) and therefore the value of the PO strip increases.

We exploit the differential exposure of the two strips to prepayments to identify OAS^Q and Λ , as illustrated graphically in the example of Figure 5. At $\Lambda = 1$, the physical prepayment speed, the OAS on the IO strip (shown in black) is about 200 basis points and the OAS on the PO (shown in grey) is about zero. As Λ increases, the OAS on the IO declines while the spread on the PO increases because of their opposite sensitivities to prepayments. The sensitivity of the OAS on the pass-through (red line) is also negative because, in this example, it is assumed to be a premium security, which suffers from prepayments as discussed in the previous section.

Graphically, for each IO/PO pair, we identify Λ as the crossing of the OAS IO and PO schedules at the point where the residual risk premium (OAS^Q) on the two strips is equalized.¹⁹ By the law of one price, the residual risk premia on the pass-through will also be equalized at this point; thus, the OAS schedule on the pass-through intersects the other two schedules at the same point. The difference between the OAS on the pass-through at the physical prepayment speed (OAS^P) and at the market-implied one (OAS^Q) is then equal to the prepayment model risk premium paid on the pass-through. More formally:

Proposition 4.1. *If the IO strip and the PO strip on a pool j have equal exposures to non-prepayment sources of risk, then, by no arbitrage, the remaining risk premia are equalized on the strips and recombined passthrough when expectations are calculated using the market-implied prepayment speed, so that*

$$OAS_{IO,j}^Q = OAS_{PO,j}^Q = OAS_{PT,j}^Q.$$

¹⁹MBS market participants sometimes calculate “break-even multiples” similar to our Λ but, to our knowledge, do not seem to track them systematically as measures of risk prices.

In the Appendix we show how this proposition applies to the theoretical setting of Section 3. We then define the prepayment model risk premium component in the OAS as:

Definition 4.1. *The prepayment model risk premium on a pass-through security (consisting of the combination of an IO and PO strip on the same underlying pool) is equal to $OAS^P - OAS^Q$.*

We apply this method to each IO/PO pair in our sample, thereby identifying pool- and date-specific Λ and OAS^Q . This allows us study time series and cross-sectional variation in the OAS^Q without imposing parametric assumptions and we can thus remain agnostic whether prepayment model or other risks could be the source of the OAS smile.²⁰ The key to this identification is the assumption that OAS^Q are equal across IO and PO strip on the same pool. One could relax this assumption by imposing a parametric form linking OAS^Q (or Λ) across pools. Alternatively one could use TBA prices (as a proxy for the value of the recombined pass-through) and make assumptions on the differential liquidity of the stripped and recombined securities to identify Λ . That said, the impact on the prepayment risk premium and OAS^Q on the pass-through will be limited for reasonable liquidity differences between IOs and POs. For example, we find that assuming OAS_{PO}^Q to be 50 basis point higher than OAS_{IO}^Q never changes OAS_{PT}^Q by more than 5 basis points relative to the baseline specification with $OAS_{IO}^Q = OAS_{PO}^Q$. Intuitively, as shown in Figure 5, the slope of the OAS_{PT} schedule in Λ is less steep than the slopes of the IO and PO schedules, and thus $OAS_{IO}^Q - OAS_{PO}^Q$ differences will have a limited effect on the recombined passthrough.

4.2 Stripped MBS data

We start with an unbalanced panel of end-of-day price quotes on all IO/PO pairs (“trusts”) issued by Fannie Mae, obtained from a large dealer, for the period January 1995 to December 2010.²¹ We merge these with characteristics of the underlying pools, using monthly factor tape data describing pool-level information obtained from the data provider eMBS. We use end-of-month prices, which we also subject to a variety of screens, as described in Appendix B. Following these data-quality filters, our data include 3713 trust-month observations, or about 19 per month on average,

²⁰One alternative approach to identify Λ would be to assume that the OAS reflects only prepayment model risk. With this approach, Levin and Davidson (2005) obtain a Q prepayment function by equalizing the OAS (relative to agency debt) on all pass-through coupons to zero. By construction, both the time series and cross-sectional variation in the OAS will then be the result of variation in prepayment model risk.

²¹We end our sample on that date because, according to market participants, IO/PO strips became less liquid after 2010, as trading started focusing on Markit’s synthetic total return swap agency indices IOS, POS and MBX instead. These indices mimic the cash flows of strips on a certain coupon-vintage (e.g. Fannie Mae 30-years with coupon 4.5 percent originated in 2009). The methods in this paper could easily be extended to those indices.

from 95 trusts total. The year with the lowest number of observations is 1999, where we have an average of 10 trusts per month, while after 2005 we have at least 20 trusts in all but one month. The original face value of securities in our sample ranges from \$200 million to about \$4.5 billion, with a median of \$2 billion. The median remaining principal balance (RPB) of trusts in months in our dataset is \$1.13 billion. In the cross-sectional analysis, we average spread measures to the coupon level (weighting by market value of the trusts), resulting in 1005 coupon-month pairs that cover most of the outstanding coupons in the Fannie Mae fixed-rate MBS universe (on average, 91 percent of remaining face value).²² A potential concern is that the IO/PO strips we have are not necessarily representative of securities traded in the TBA market, to which we are comparing our model output. As we will see, however, we obtain similar spread patterns based on IO/PO prices, both in the time series and cross section. One advantage of the stripped MBS data that we are using relative to TBAs, which trade on a forward “cheapest-to-deliver” (CTD) basis, is that we do not need to make assumptions about the characteristics of the security.

4.3 Interest rate and prepayment model

A standard MBS pricing model has two main components: an interest rate and a prepayment model. The two are combined to simulate interest rate paths and corresponding prepayment flows to obtain model prices and spreads. We use a three-factor [Heath et al. \(1992\)](#) interest rate model, calibrated at month-end to the term structure of swap rates and the interest rate volatility surface implied by the swaption matrix, by minimizing the squared distance between the model-implied and the observed volatility surface. We obtain swap zero rates from an estimated Nelson-Siegel-Svensson curve. Details on the interest and yield curve model are provided in [Appendix D](#).

The academic literature has considered either structural/rational prepayment models (e.g., [Dunn and McConnell, 1981a,b](#); [Stanton, 1995](#)) or reduced-form statistical prepayment models estimated on historical data (e.g., [Richard and Roll, 1989](#); [Schwartz and Torous, 1989](#)). While structural models are more appealing, MBS investors favor reduced-form models (see, e.g., Section 4 of [Fabozzi, 2006](#)), for example, because in tranching CMOs, cash flows depend on prior prepayments, whereas structural models are solved by backward induction ([McConnell and Buser, 2011](#)). We follow standard industry practice and use a reduced-form prepayment model.

²²As in [Figure 1](#), this means that the range of trust coupons in which the remaining face value is concentrated shifts downward over time. For instance, in January 1995, about 90 percent of the face value of securities for which we have quotes is in 7, 7.5, or 8 percent coupon securities. In January 2003, over 90 percent are in 5.5, 6, 6.5, or 7 percent securities. Finally, in December 2010, the last month in our data, the most prominent coupons are 4, 4.5, 5, and 5.5, which together account for 88 percent of face value.

Practitioner models vary in the choice of controls and weighting rules for historical data (though the exact details of these models are not publicly available). Additionally, practitioners often make ad-hoc adjustments to incorporate likely effects of expected or announced policy changes affecting prepayments (for instance, the Home Affordable Refinance Program in 2009 or the introduction of additional agency fees on new mortgages since 2007). Therefore, in order to better capture market participants' expectations and be consistent with their pricing and spreads, we do not estimate our model on historical data, but instead extract prepayment model parameters from a survey of dealer models from Bloomberg LP. In these surveys, major MBS dealers provide their model forecasts of long-term prepayment speeds under different constant interest rate scenarios (with a range of +/- 300 basis points relative to current rates).²³ Carlin et al. (2014) use these data to study the pricing effects of investors' disagreement measured from "raw" long-run prepayment projections. We, instead, extract model parameters of a monthly prepayment function that are necessary to compute the OAS, by explicitly accounting for loan amortization, the path of interest rates, and changes in a pool's borrower composition.

Prepayment sensitivities to interest rates and other factors differ over time and across securities, and we thus estimate model parameters from average survey responses for each security and date. We model the date τ single-month mortality rate (SMM), which is the fraction of a pool that prepays, of security j to match the average projected long-run survey speed for the different interest rate scenarios. These scenarios provide information on a pool's prepayment sensitivity to the incentive to refinance (INC_τ^j). The functional form of our prepayment model is:

$$s_\tau^j = \chi_\tau^j s_{1,\tau}^j + (1 - \chi_\tau^j) s_{2,\tau}^j \text{ for } t < \tau \leq t + T_j \quad (4.1)$$

where

$$s_{i,\tau}^j = b_1^j \min \left(\text{WALA}_\tau^j / 30, 1 \right) + \kappa_i \cdot \frac{\exp \left(b_2^j + b_3^j \cdot \text{INC}_\tau^j \right)}{1 + \exp \left(b_2^j + b_3^j \cdot \text{INC}_\tau^j \right)} \text{ for } i = 1, 2. \quad (4.2)$$

A key feature of the time evolution of MBS prepayments is the so-called burnout effect, which is the result of within-pool heterogeneity in the borrowers' sensitivity to the refinancing incentive. Because more sensitive borrowers are the first to exit the pool when rates decline, the pool's overall sensitivity to interest rates drops over time even if interest rates are unchanged.²⁴ To capture

²³Until May 2003, dealers provided a single set of forecasts for each coupon (separately for Fannie Mae, Freddie Mac, and Ginnie Mae pass-through securities); since then, they provide separate forecasts for different vintages (for instance, a 5.5 percent coupon with average loan origination date in 2002 versus a 5.5 percent coupon with origination in 2005).

²⁴In the extreme, some borrowers never refinance even when their option is substantially in the money. Possible

this effect, we assume the pool is composed of two types of borrowers: fast refinancers (group 1) and slow refinancers (group 2), with respective shares χ_τ and $1 - \chi_\tau$. As shown in equation (4.1), total pool prepayments are share-weighted averages of each group’s prepayment speed. Each group’s prepayment depends on two components. The first, which is identical to both groups, is governed by b_1 and accounts for non-rate-driven prepayments, such as housing turnover. Because relocations are less likely to occur for new loans, we assume a seasoning of this effect using the industry-standard “PSA” assumption, which posits that prepayments increase for the first 30 months in the life of a security (WALA, or weighted average loan age) and are constant thereafter. The second component captures the rate-driven prepayments due to refinancing. This is modeled as a logistic function of the rate incentive (INC), with a sensitivity κ_i that differs across the two groups: $\kappa_1 > \kappa_2$. Since group 1 prepays faster, χ_τ declines over time in the pool. This changing composition, which we track in the estimation, captures the burnout effect. We provide more detail on the prepayment model and parameter estimation in Appendix D.²⁵

Figure 6 shows estimated prepayment functions for different loan pool compositions and using average parameters b_1, b_2, b_3 across all securities in our sample. Prepayments (at an annual rate, or CPR) display the standard S-shaped prepayment pattern of practitioner models. They are not very sensitive to changes in interest rates (and thus INC) for securities that are deeply ITM or OTM, but highly sensitive at intermediate moneyness ranges. The black (top) line shows that a pool with $\chi = 1$ reaches a maximum predicted CPR of about 75 percent when it is deeply ITM, in contrast to only 35 percent when the share of fast refinancers is only 0.25 (red line). Thus, the changing borrower composition, even with a constant INC, implies a decline in prepayments over time because of the pool’s burnout (decreasing χ).

5 Model results

Our pricing model produces standard MBS spread measures as well as the OAS^Q , which is adjusted for (or risk-neutral with respect to) not only interest rate risk but also prepayment model risk. In this section we present the output of the model in terms of spreads in the cross section and

reasons for this non-exercise of the prepayment option are unemployment or other credit problems (Longstaff, 2005) or a lack of financial sophistication (sometimes called “woodhead” behavior; Deng and Quigley, 2012).

²⁵A notable detail is that in our model, we define INC as the end-of-month 10-year swap rate minus the pool’s WAC. This is different from the “true” interest rate incentive faced by a borrower, which would be the mortgage rate minus WAC. However, our formulation has the major advantage that it does not require us to specify a model for the gap between mortgage rate and swap rate. The average gap between 30-year FRM rate and the 10-year swap rate over our sample period is about 1.2%.

time series. We then relate average OAS^Q and prepayment model risk premia to fixed-income and MBS-specific risk measures in order to help interpret model results and variation in MBS spreads. We finally discuss the response of MBS spreads to the Fed’s first LSAP announcement in November 2008.

5.1 OAS smile

The cross-sectional results are summarized in Figure 7. Similar to our findings for the TBA spreads (Figure 3), the OAS exhibit a smile in the security’s moneyness (panel a): they are lowest for securities that trade close to par and increase as an MBS goes either OTM, or especially, ITM. As shown in panel (b), the OAS^Q , which strips prepayment model risk from the OAS, does not appear to vary significantly with moneyness, suggesting that differences in liquidity do not contribute to the OAS smile. Instead, as shown in panel (c), the difference between the OAS and OAS^Q closely matches the smile pattern in the OAS; in other words, the differential exposure to prepayment model risk explains the cross-sectional pattern in the OAS. Additionally, panel (d) displays the difference in implied long-run prepayment speeds between the risk-neutral (Q) and physical (P) prepayment models. OTM securities tend to have slower risk-neutral speeds, while ITM securities tend to have faster risk-neutral speeds. Thus, in both cases the risk-neutral model tilts the prepayment speeds in the undesirable direction from the point of view of the investor. That is, market prices imply that prepayments are faster (slower) for securities that suffer (benefit) from faster prepayments, which is exactly what one would expect as market-implied prepayments include compensation for risk. Finally, just as in the TBA market, the option cost is hump-shaped (panel f), which as discussed before can be explained analogously to the hump-shaped pattern of an option’s Vega (sensitivity to changes in the volatility for the underlying).

In Tables 3 and 4, we use regressions to study if the cross-sectional patterns in the two components of OAS are robust to including month fixed effects (in order to focus on purely cross-sectional variation) and to ending the sample before the financial crisis period. As in the earlier Table 2, we sort the different coupons in bins by moneyness, with ATM securities (moneyness between -0.25 and +0.25) as the omitted category.²⁶ Table 3 shows that there is little systematic pattern in OAS^Q across bins; results in columns (2) and (4) suggest in fact that ATM coupons may have slightly *higher* OAS^Q than the surrounding coupons, but the differences are small. There

²⁶We use fewer bins because our IO/PO strips have less coverage of very deeply OTM (moneyness < -1.75) or ITM (moneyness > 2.75) coupons.

is some evidence that the most deeply ITM coupons (moneyness > 2.25) may command a positive premium, which could be driven by the reduced liquidity of these (generally very seasoned) coupons. Turning to the prepayment model risk premium, Table 4 shows that the (slightly tilted) smile pattern shown in panel (d) of Figure 7 is robust to the addition of month fixed effects and excluding the financial crisis period. The coefficients suggest that the magnitude of the prepayment model risk premium is economically meaningful: securities that are 1.25 percentage points or more ITM command a premium of 20 basis points or more relative to ATM securities.

In sum, while the prepayment model risk premium in the cross section is strongly linked to the moneyness of the securities, we find little evidence that this is also the case for the remaining risk premium (OAS^Q), suggesting that differential liquidity across coupons is likely not a major driver of cross-sectional variation in spreads (except perhaps for the most deeply ITM securities).

5.2 Time series variation

We now turn to the variation in the average OAS. As in Section 2, we construct a market value-weighted index.²⁷ Comparing the OAS (black line) and ZVS (grey line) in Figure 8 to the corresponding measures in Figure 2 confirms that our model output is close to the dealer counterparts. As in their models, the level of the average OAS is close to zero, but increases in periods of stress. Further, the difference between OAS and OAS^Q is small and the two series tightly co-move, meaning that much of the OAS variation results from changes in OAS^Q (red line). Thus, although it is an important determinant of the cross-sectional variation in spreads, prepayment model risk does not appear to be the dominant driver of the OAS time series variation. Indeed as shown in Figure 1, the value-weighted share of deeply OTM or ITM securities is limited, and these securities earn most compensation for prepayment risk. This arises because most securities are issued at, or close to, par. However, prepayment model risk in the MBS universe can be significant when mortgage rates move sharply, as in early 1998, the summer of 2003, and in 2009 and 2010 when mortgage rates reached historic lows and the gap between OAS and OAS^Q widened.

We now turn to the determinants of the time series variation in OAS, and in particular its two components OAS^Q and the prepayment model risk premium. Panel (a) of Table 5 replicates the TBA analysis in Table 1, showing that average OAS are strongly related to credit spreads (while ZVS variation is explained by changes in swaption volatility). In panel (b) we regress the

²⁷We do this by first averaging spreads within coupons (weighting by IO/PO values) and then across coupons (weighting by market values based on TBA prices).

OAS, and its components, on mortgage-specific risk factors, such as spreads on agency debt (or debentures) relative to swaps, agency MBS issuance (normalized by broker-dealer book equity, and subtracting Fed MBS purchases in 2009 and 2010), as well as the average squared moneyness of the MBS universe.

We find that average OAS^Q are related to spreads on (unsecured) agency debentures. As noted earlier, agency MBS are typically perceived as being free of credit risk, but since the government guarantee on securities issued by Fannie Mae is only implicit, investors' perceptions of this guarantee (along with the perceived credit risk of agencies) may change over time and thus affect both spreads on agency debt and MBS. In particular, both OAS^Q and agency debt spreads increased in the fall of 2008, when Fannie Mae and Freddie Mac were placed in conservatorship by the US Treasury. The spreads on MBS and agency debt do, however, also co-move earlier in the sample, pointing to other common factors such as liquidity and funding costs of these securities.²⁸

Credit spreads (Baa-Aaa) continue to be significantly related to OAS, mostly through OAS^Q rather than the prepayment risk component. The sensitivity of OAS^Q to credit spreads suggests common pricing factors in the MBS and credit markets, such as limited risk bearing capacity of financial intermediaries (see, for example, [Shleifer and Vishny, 1997](#); [Duffie, 2010](#); [Gabaix et al., 2007](#); [He and Krishnamurthy, 2013](#)). In these models, financial intermediaries are marginal investors in risky assets; when their financial constraints bind, their effective risk aversion increases, raising risk premia in all markets. Thus, when the supply of risky assets relative to intermediaries' capital decreases, financial constraints are relaxed lowering required risk compensation. In line with these predictions, we find that the supply of MBS, measured by issuance relative to market-to-market equity of brokers and dealers, explains OAS^Q time series variation. We explore this channel further in the next section, where we study the effects of Fed MBS purchases, which absorb supply in the hands of investors, on the OAS and its components.

Finally, as previously discussed, the OAS smile implies that spreads, and in particular their prepayment risk component, are largest for deeply OTM and ITM securities. This suggests that when the market-value weighted moneyness is either very positive or very negative, the average OAS and prepayment model risk premium ($OAS^P - OAS^Q$) should be large. We test for this

²⁸The spread between Fannie Mae debentures and Treasury bonds of equal maturity fell following the conservatorship announcement, but then substantially increased through the end of 2008. Since there should have been essentially no difference in the strength of the debt guarantee between debentures and Treasuries at that point, and since the spread widening was stronger for shorter maturity bonds, [Krishnamurthy \(2010\)](#) argues that this reflects a flight to liquidity. In line with this interpretation, our OAS^Q also reaches substantially higher levels in October compared to August 2008, despite the reduction in credit risk to investors.

channel by regressing on average squared moneyiness, and find it to positively affect the average prepayment model risk premium.

5.3 Interpreting the OAS response to the Fed's LSAPs

As discussed above, MBS spreads are positively related to MBS supply, a finding that is consistent with intermediary asset pricing models with limited risk-bearing capacity. In this section we provide additional evidence on this channel by focusing on the Fed's large-scale asset purchase (LSAP) program. The program has entailed an unprecedented shift in the composition of the MBS investor base as the Fed now holds more than a quarter of the total agency MBS universe—up from nothing prior to the financial crisis. We decompose spreads using our pricing model and show how it explains the fanning out in OAS across different coupons following the initial announcement of the program.

We focus on spread movements after November 25, 2008, when the Fed announced its first round of purchases of up to \$500 billion in agency MBS.²⁹ Based on the current coupon MBS, which is the focus of much of the research on this topic—with the important exception of [Krishnamurthy and Vissing-Jorgensen \(2013\)](#) which we discuss in the paper's conclusion—the announcement had a substantial effect on the MBS market (see, e.g., [Gagnon et al. 2011](#) or [Hancock and Passmore 2011](#); [Stroebel and Taylor 2012](#) are more skeptical). According to different dealer models, the current coupon OAS, which had been at record levels of 75–100 basis points over October and November 2008, fell 30-40 basis points on the day of the announcement, and stayed around the lower level afterwards. Consistent with the decline in secondary MBS spreads and yields, headline 30-year fixed-rate mortgage rates dropped nearly a full percentage point between mid-November and year-end 2008.

Spread movements on the current coupon MBS alone hide significant heterogeneity across the coupon stack, as evidenced by the series in [Figure 9](#), which are median spreads across dealer models (the same used in [Section 2](#)) for the four main coupons traded at that time. Adjusted spreads (top panel) that were all at similarly elevated levels in the fall of 2008 fanned out (diverged) following the announcement. Between October and November 2008, OAS on low coupons (4.5 and 5) fell, while, over the same period, those on higher coupons were little changed and then even widened through the end of December. As discussed in prior sections, understanding the OAS

²⁹The Fed also announced that it would purchase up to \$100 billion in agency debt. The purchases began in early January 2009. The program was then extended in March 2009, when it was announced that an additional \$750bn in agency MBS, \$100bn in agency debt, and \$300bn in long-term Treasuries would be purchased over the following year.

component is crucial to explaining the basis, which in addition reflects changes in implied interest rate volatility that are easier to understand. Indeed, as implied volatility rose over the month of November, the MBS option cost widened and so did the ZVS (bottom panel of Figure 9).³⁰

The earlier findings from our model suggest two potentially countervailing effects of Fed MBS purchases on OAS. On the one hand, Fed purchases reduce MBS supply to be absorbed by risk-sensitive investors, thereby reducing the required risk premium on all MBS (through OAS^Q). On the other hand, movements in mortgage rates associated with such purchases alter securities' moneynesses, shifting the OAS along the smile by changing the prepayment model risk premium.

The results from our model are shown in the bottom panel of Figure 10. First, OAS movements (in black) for IO/PO pass-throughs are similar to the TBA ones. In terms of the MBS supply effect, we discussed above how the OAS^Q component is flat across coupons and declines with a reduction in MBS supply. Consistent with this, we find that the OAS^Q evolves similarly for the 4.5, 5, and 5.5 coupons. For the 6 coupon, OAS^Q increases in November and December, before dropping toward the level of the other coupons in January as actual LSAP purchases begin. The OAS^Q effect thus suggests that the LSAP program lowered non-prepayment risk premia across the coupon stack.³¹

The cross-coupon "homogeneous" OAS^Q impact of the Fed's policy is, however, masked by changes in the prepayment model risk premia that vary with MBS moneyness, shown in the top panel of Figure 10. The 4.5 starts out OTM and moves ATM as mortgage rates drop, while the 5.5 and 6, which are around ATM in October, move quite deeply ITM. Based on the OAS smile, the 4.5 should command a prepayment model risk premium prior to November and the 5.5 and 6 coupons afterward. The bottom panel shows that this is indeed the case: the narrowing in the gap between the black and grey lines means that the decrease in the OAS of the 4.5 coupon is in part due to the decrease in its prepayment model risk exposure following the drop in rates. In contrast, the prepayment model risk premia on the 5.5 and 6 coupons are high from December onward as they move deeply ITM and are more sensitive to prepayment model risk.³²

In sum, increases in the moneyness of high coupons following the November 2008 LSAP an-

³⁰For instance, the 2-year-into-10-year swaption implied volatility increased by more than half, from 25 basis points at the end of October to above 40 at the end of November. Most of this increase occurred prior to the LSAP announcement on November 25.

³¹In addition to the supply effect, the Fed announcement may also have strengthened the perceived government backing of Fannie Mae and Freddie Mac and improved the liquidity of agency securities (Hancock and Passmore, 2011; Stroebel and Taylor, 2012).

³²The strips we have available do not necessarily have the same characteristics as what the dealers assume to be cheapest-to-deliver in TBA trades; therefore, our OAS levels do not exactly line up with theirs for all coupons in all months. Nevertheless, patterns are very similar, especially in changes.

nouncement led to an increase in their prepayment model risk premium, which explains why their OAS did not fall, even though OAS^Q declines across the coupon stack as the Fed started absorbing MBS supply. We discuss the policy implications of these results below.

6 Conclusions

We have analyzed determinants of the mortgage basis and, especially, of option-adjusted spreads, which are a measure of risk premia in MBS after accounting for interest rate uncertainty. In the MBS cross section we uncover the OAS smile, meaning that OAS tend to be lower for ATM coupons than for others. Our pricing model, which relies on information from stripped MBS prices, attributes the OAS smile to prepayment model risk, which is the risk of over- or under-predicting future prepayments for given interest rates. In the time series, we find that variation in average OAS is primarily driven by non-prepayment risk factors, which are linked to credit spreads, MBS supply, and spreads on other agency debt. These results suggest that risk-bearing capacity of MBS investors, as well as the liquidity and default risk of agency securities, is time-varying and affects the valuation of MBS relative to benchmark interest rates.

Our model sheds light on the effects of the Fed's MBS purchases—a key component of unconventional monetary policy in recent years—and on the monetary transmission channel more generally. The effect of central bank balance sheet expansion on asset prices has been highly debated. One view is that the central bank's asset composition is irrelevant and Fed purchases of long-term securities such as Treasuries and MBS matter only to the extent that they boost high-powered money through the Fed's liabilities (the quantitative easing channel of [Friedman, 2000](#)), or signal commitment to future short-term interest rate policies (signaling channel as in [Woodford, 2012](#)). Under an alternative view the Fed's asset composition directly affects asset prices (credit easing channel; [Bernanke, 2009](#)). [Gagnon et al. \(2011\)](#), building on [Greenwood and Vayanos \(2014\)](#) and others, argue that Fed purchases of any long-term asset (that is, either MBS or Treasuries) affect term premia on fixed income assets by reducing the market price of duration risk. [Krishnamurthy and Vissing-Jorgensen \(2011\)](#) instead argue that Fed purchases have more subtle pricing implications and mainly affect the price of the securities being purchased, rather than having cross-asset effects such as lowering fixed income duration risk.

As we discussed in the previous section, following the announcement of the first LSAP program in November 2008, OAS decreased substantially, which is consistent with Fed purchases

having a disproportionate effect on the targeted assets. We also showed that OAS on low coupons fell substantially more than those on high coupons, which our model explains as: (i) the OAS^Q falling (roughly) equally across coupons as the Fed absorbs supply and lowers the risk premia required by specialized investors; and (ii) high coupons moving substantially ITM, which increases the prepayment model risk premium on those coupons and prevents their total OAS from falling.

These heterogeneous responses across MBS are not specific to monetary policy changes in 2008/9, a period in which severe market disruptions may have affected the response to Fed interventions. For example, [Krishnamurthy and Vissing-Jorgensen \(2013\)](#) discuss the “taper tantrum” episode around the June 19, 2013 FOMC meeting, when rates backed up on investors’ fears that the Fed would start reducing its purchases earlier than previously thought. Around this event, OAS increased substantially for low coupons, while OAS on higher coupons stayed almost unchanged. [Krishnamurthy and Vissing-Jorgensen](#) interpret this latter fact as evidence that capital constraints (or limited risk-bearing capacity) are unimportant at that time.³³ Instead, they argue that the increase in lower-coupon OAS comes about because the “scarcity effect” for low coupons weakens as the anticipated Fed demand for those coupons decreases.³⁴ Based on this interpretation, they argue that the Fed could sell the higher coupons from its MBS portfolio without causing an increase in production-coupon OAS.

Our model, which does not rely on cross-coupon segmentation, suggests a different explanation for the reaction to the June 2013 events: the increase in the quantity of securities that non-Fed investors have to hold because the anticipated taper increases the required risk premium (through OAS^Q) on all MBS; however, because rates increase at that point, the prepayment model risk premium on high coupons (that were previously deeply ITM) falls, so that their overall OAS remains roughly constant.³⁵ Because of the differential prepayment model risk exposure across MBS, the stability in high-coupon OAS around this event is thus *not* evidence of a lack of capital constraints for MBS investors, implying that potential sales of high coupons might still increase OAS on lower

³³They argue that the “capital constraints” channel was the main channel responsible for the decrease in OAS following the November 2008 announcement, in line with our discussion in the previous section.

³⁴Krishnamurthy and Vissing-Jorgensen’s MBS scarcity channel, which is specific to the TBA market, implies larger spread responses for coupons directly targeted by Fed purchases. According to this channel, as demand for a specific coupon increases, the quality of pools delivered in the TBA contract (as measured by their prepayment characteristics) improves, so that the equilibrium price increases to elicit pool delivery. Because this scarcity channel works at the level of each coupon, it predicts that Fed purchases do not affect risk premia on non-targeted MBS, such as higher coupon TBAs or MBS not deliverable in the TBA market (e.g. those backed by loans originated under the Home Affordable Refinancing Program with loan-to-value ratios exceeding 105%).

³⁵The 10-year Treasury yield increased by 40 basis points from June 18 to June 25; the Freddie Mac headline FRM rate even increased by more than 50 basis points.

coupons and therefore increase mortgage rates.

From a broader perspective, this paper provides evidence for intermediary asset pricing in fixed income markets. Recent literature (such as [He and Krishnamurthy, 2013](#); [Brunnermeier and Sannikov, 2014](#)) has proposed that intermediaries' risk bearing capacity impacts risk premia during periods of market stress. While we do find that OAS^Q narrowed across coupons as the Fed reduced the outstanding stock of MBS available to private investors through its LSAP program, the OAS^Q reacts to changes in the outstanding supply of MBS even during normal market conditions. The latter finding is consistent with theories (e.g. [Gromb and Vayanos, 2002](#); [Brunnermeier and Pedersen, 2009](#); [Adrian and Boyarchenko, 2012](#)) that link risk premia to intermediary balance sheet constraints even in periods when intermediaries are well capitalized.

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Figure 1. Share of total MBS value by coupon Each shaded grey area represents the share (left axis) of total balance in the 30-year fixed rate mortgage universe accounted for by MBS with a given coupon (heat map in the right panel). The red line is the current coupon TBA (right axis).

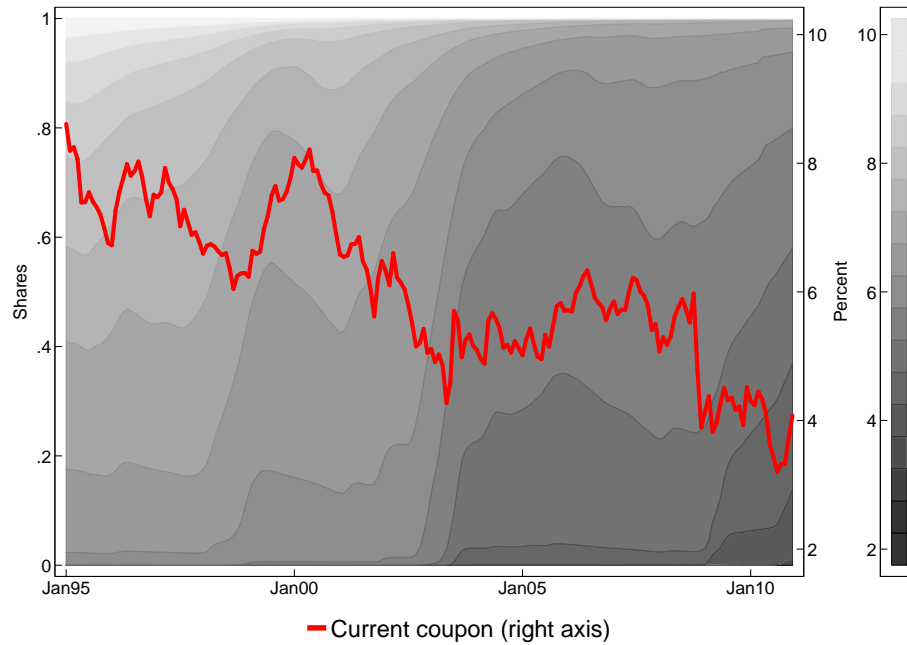


Figure 2. Time series evolution of spreads on the TBA index This figure shows time series variation in option-adjusted (OAS) and zero-volatility (ZVS) spreads on a value-weighted index based on TBA quotes from six dealers. Additional detail is available in [Section 2](#).

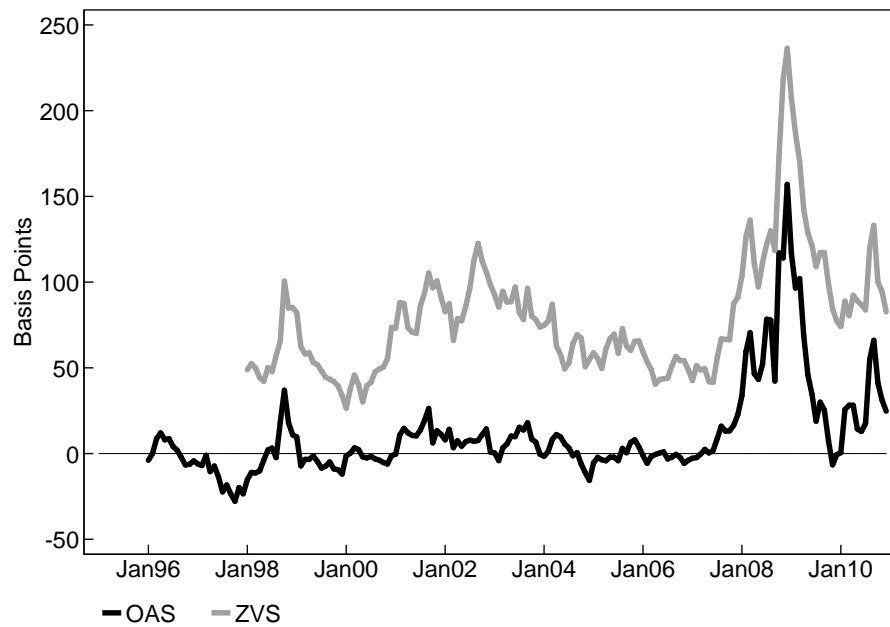


Figure 3. Cross-sectional variation in spreads and prices of MBS in TBA market The panels show scatterplots and local smoothers of the cross-sectional variation in OAS, ZVS, option cost (ZVS-OAS) and price for MBS coupons with remaining principal balance (in 2009 dollars) of \$100 million or more.

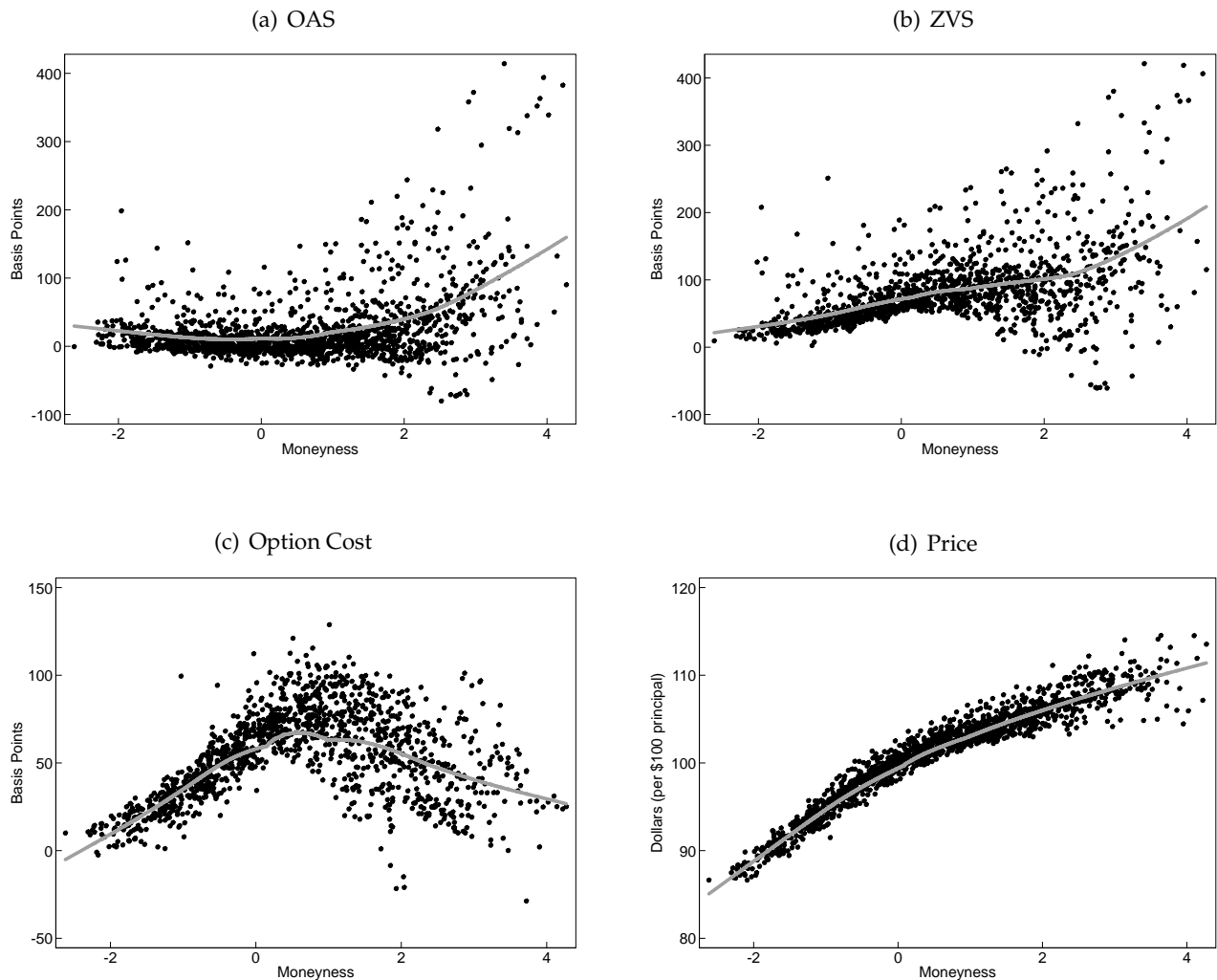


Figure 4. MBS cash flows for different prepayment speeds The colored areas represent cash flows for a hypothetical MBS with original principal of \$100, note rate of 4% and coupon of 4.5% in a slow (top panel) and a fast (bottom panel) prepayment scenario.

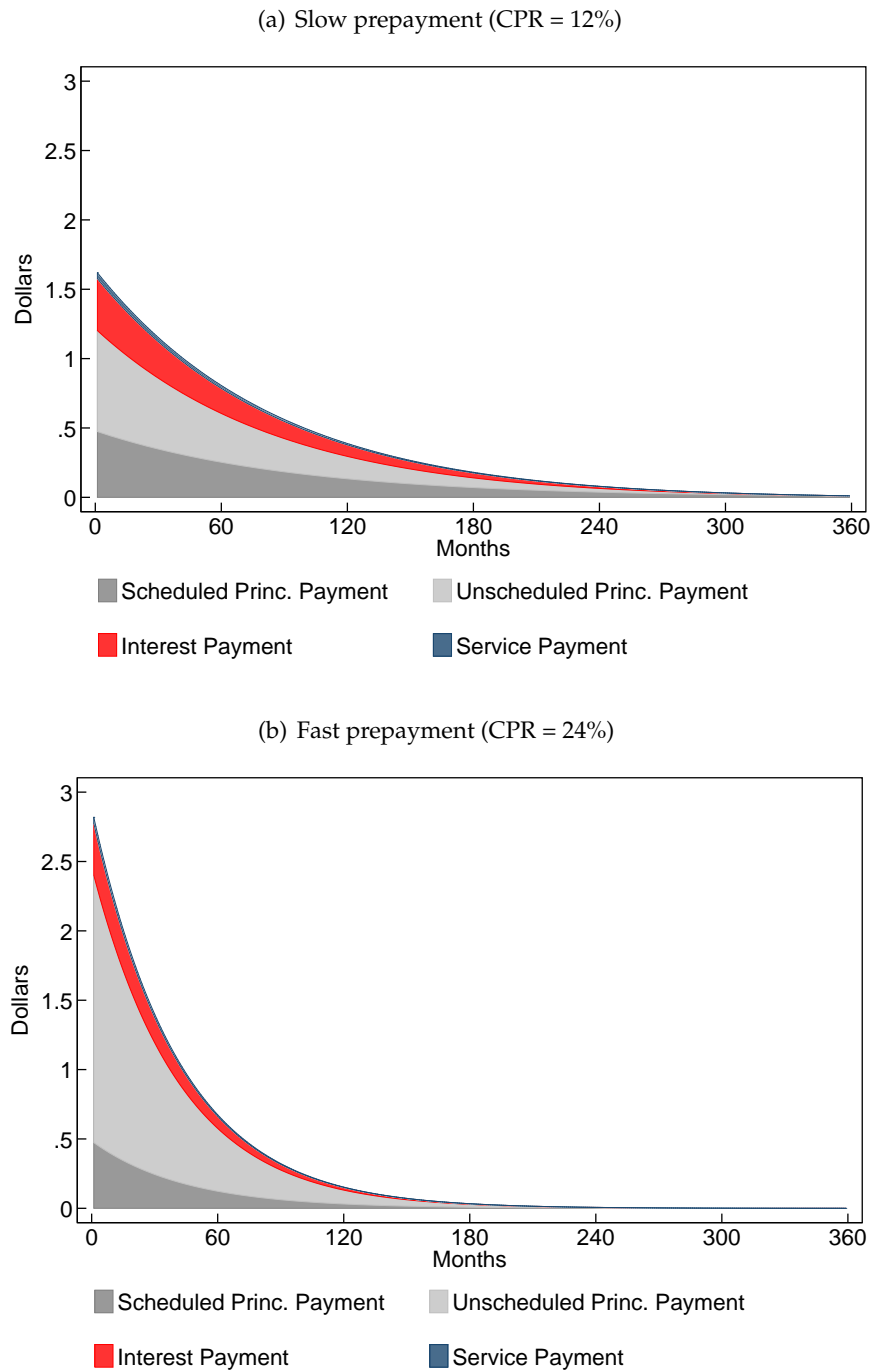


Figure 5. Graphical explanation of the model identification The figure shows OAS on the IO, PO and pass-through as a function of the multiple (Λ) on the historical prepayment speed. The OAS on the IO (PO) declines (increases) in Λ . The OAS on the pass-through in this example also declines in Λ because the pass-through is a premium security ($P^{IO} + P^{PO} > \$100$). The three OAS differ at the historical speed (Λ) but are equalized and equal to OAS^Q at the risk-neutral speed.

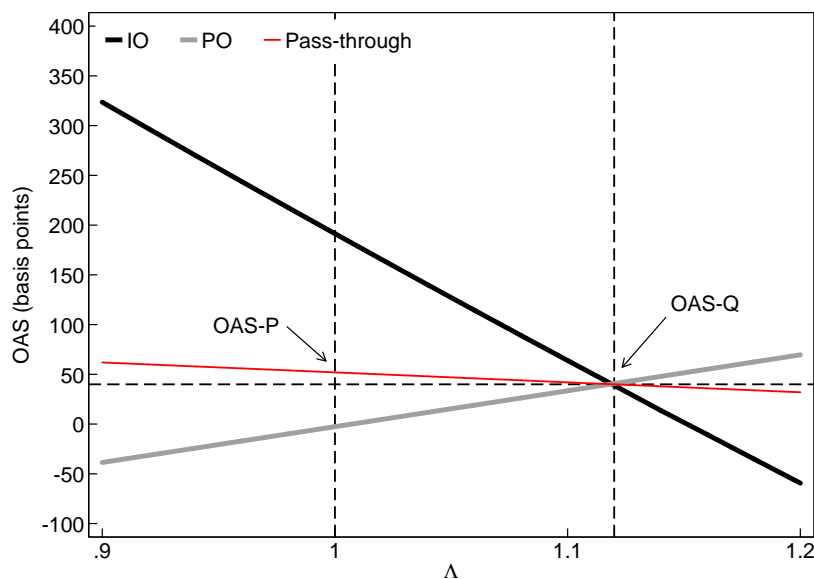


Figure 6. S curve for different pool compositions The figure shows the prepayment function in equation (4.1) with parameters b_1, b_2 and b_3 equal to their averages across securities in our sample for different levels of the fraction χ of borrowers with high interest rate sensitivity. The vertical axis is the annualized “conditional prepayment rate” (CPR) and the horizontal axis is the incentive to prepay.

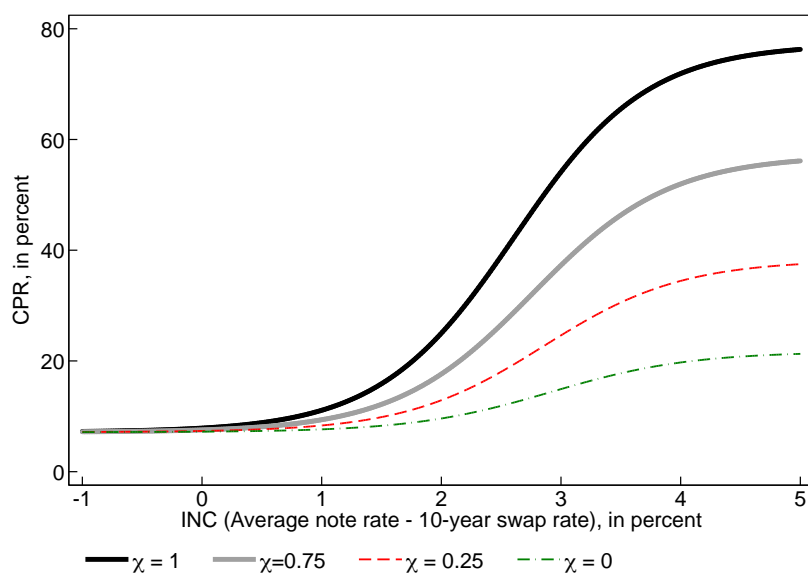


Figure 7. Cross-sectional variation in spreads on pass-throughs The panels show scatterplots and local smoothers of the cross-sectional variation in OAS, ZVS, OAS^Q , option cost (ZVS-OAS) and the difference between the historical and market-implied prepayment speed using IO/PO prices and our pricing model. Additional detail is available in Section 5.

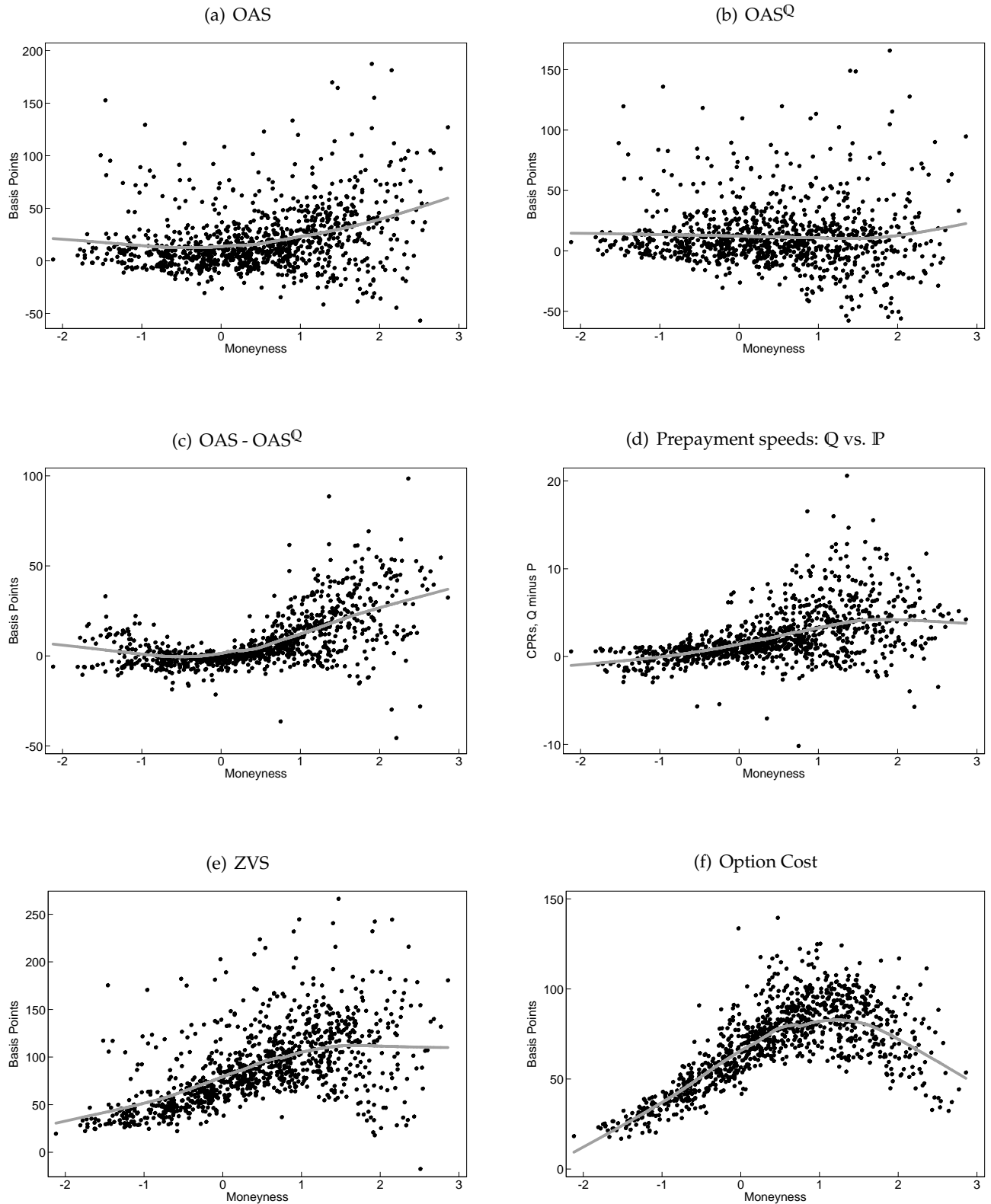


Figure 8. Time series evolution of spreads on the pass-through index This figure shows time series variation in option-adjusted spreads (OAS), OAS^Q and zero-volatility spreads (ZVS) on a value-weighted index based on IO/PO prices and our pricing model. Additional detail is available in Section 5.

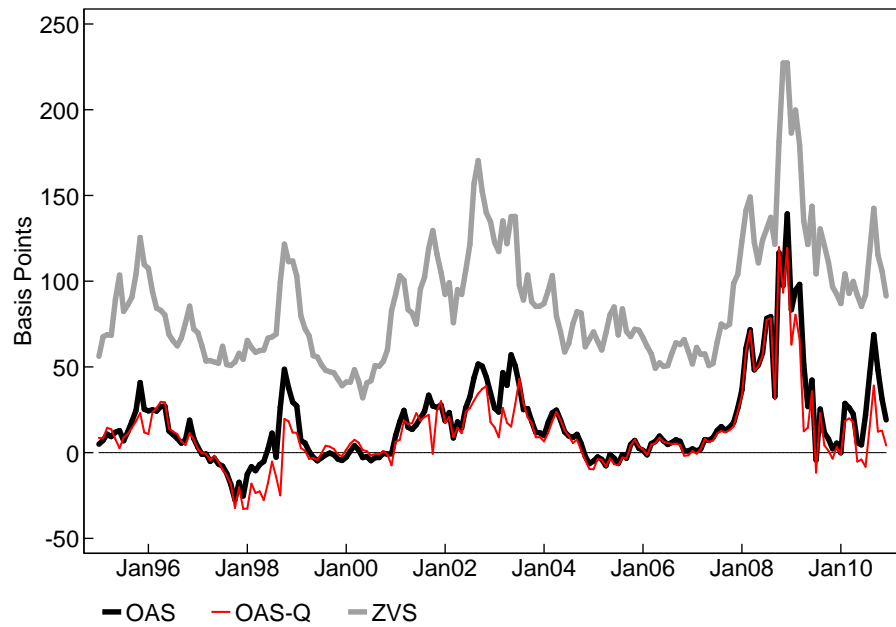


Figure 9. Spreads around LSAP1 announcement The panels show movements in ZVS and OAS for the four main coupons from August 2008 to May 2009, based on median TBA quotes from dealers.

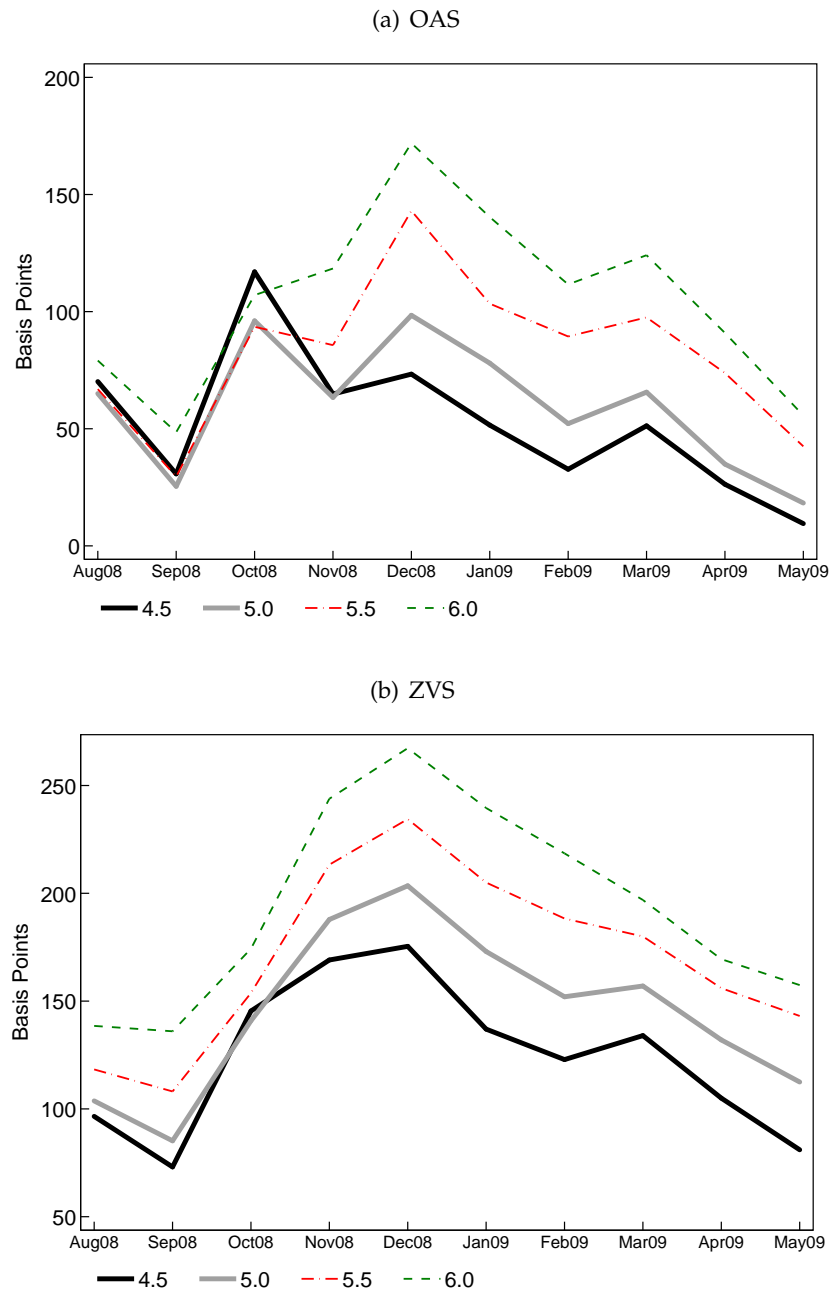


Figure 10. OAS decomposition around LSAP1 announcement This figure shows the MBS moneyiness by coupon (upper panels) and movements in OAS and OAS^Q (bottom panels) based on IO/PO quotes and our prepayment model.

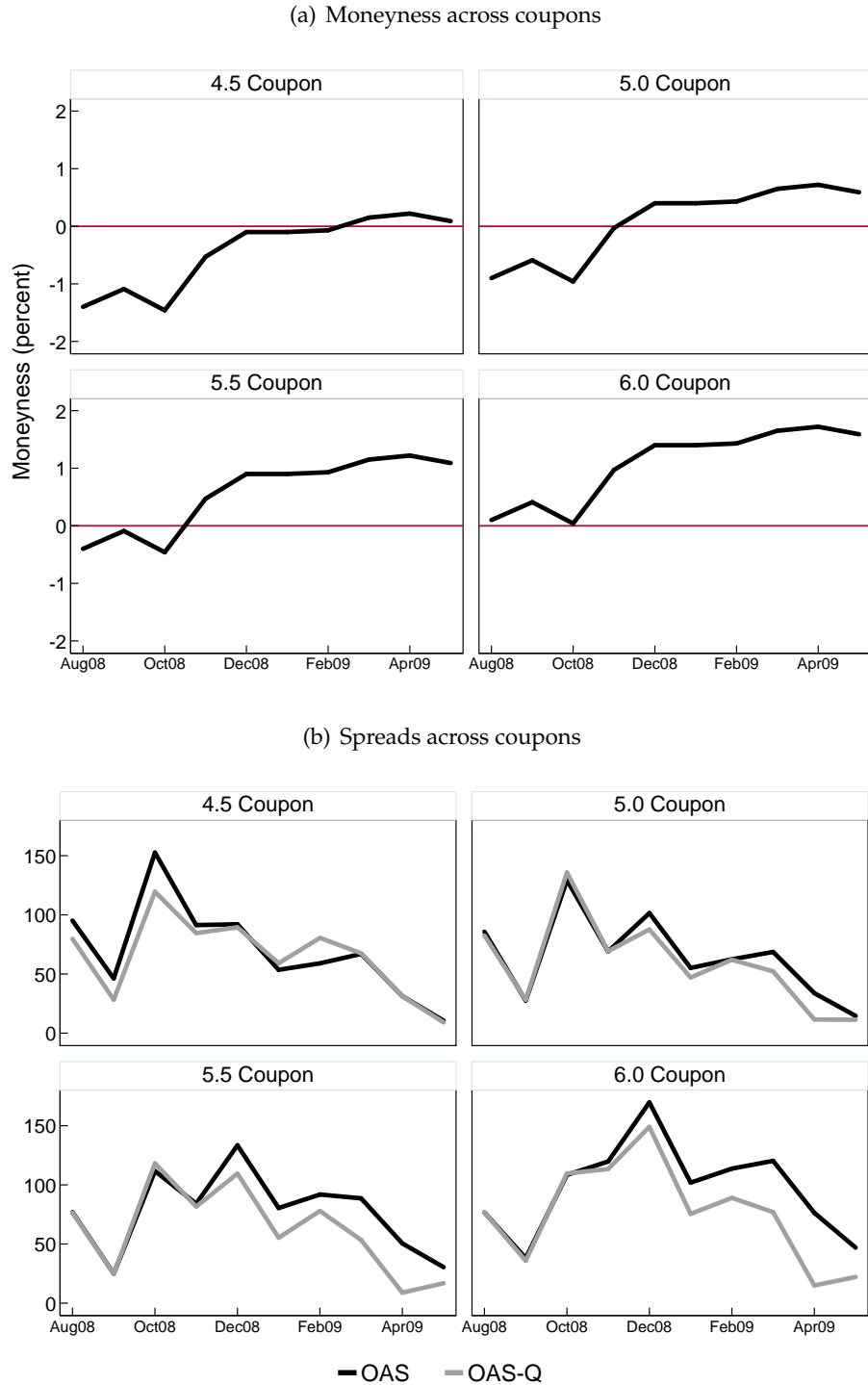


Table 1: Time series regressions on TBA index. Coefficient estimates from OLS regression of spreads reported in the top row on the Aaa-Treasury spread, the Baa-Aaa spread, the 10-year to 3-month slope of the Treasury curve and the 2-year into 10-year swaption implied volatility. All regressors are standardized to have zero mean and unit standard deviation. Newey-West standard errors (6 lags) in brackets. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

| | (1) OAS | | (2) ZVS | | (3) OAS | | (4) ZVS | |
|---------------|---------------|-------|---------------|-------|---------------|-------|---------------|-------|
| Aaa - Treas | 3.2** | [1.5] | 6.5*** | [2.3] | 2.3* | [1.2] | 6.5*** | [2.0] |
| Baa - Aaa | 19.6*** | [3.4] | 15.5*** | [2.2] | 9.7** | [3.8] | 12.1*** | [2.7] |
| Treas Slope | -0.5 | [2.4] | -0.2 | [1.3] | 2.0 | [1.3] | -0.8 | [1.5] |
| Swaption Vol. | 2.7 | [4.2] | 15.5*** | [2.5] | -0.8 | [2.4] | 22.7*** | [3.2] |
| Const | 8.8*** | [1.8] | 70.9*** | [1.8] | 3.6*** | [1.3] | 71.8*** | [1.5] |
| Adj. R2 | 0.76 | | 0.88 | | 0.31 | | 0.77 | |
| Obs. | 180 | | 156 | | 139 | | 115 | |
| Dates | 199601.201012 | | 199801.201012 | | 199601.200707 | | 199801.200707 | |

Table 2: Cross section of OAS on TBA coupons. Coefficient estimates from OLS regression of the OAS on different moneyness level bins either including or excluding time fixed effects. Newey-West standard errors (6 lags) in brackets. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

| | (1) | | (2) | | (3) | | (4) | |
|----------------|---------------|--------|---------------|--------|---------------|-------|---------------|-------|
| < -1.75 | 18.7*** | [4.5] | 18.0*** | [2.5] | 14.9*** | [2.0] | 14.1*** | [2.5] |
| [-1.75, -1.25) | 8.9*** | [1.9] | 10.4*** | [1.7] | 7.7*** | [1.2] | 8.3*** | [1.5] |
| [-1.25, -.75) | 4.0*** | [1.0] | 5.3*** | [1.2] | 4.3*** | [0.9] | 4.8*** | [0.9] |
| [-.75, -.25) | -0.0 | [0.4] | -0.1 | [0.4] | 0.8* | [0.4] | 0.8* | [0.4] |
| [.25, .75) | 1.5*** | [0.5] | 1.5*** | [0.6] | -0.1 | [0.4] | -0.1 | [0.4] |
| [.75, 1.25) | 6.4*** | [1.2] | 6.4*** | [1.3] | 2.6*** | [0.9] | 2.5*** | [1.0] |
| [1.25, 1.75) | 15.6*** | [2.2] | 15.0*** | [2.2] | 7.2*** | [1.8] | 7.2*** | [1.9] |
| [1.75, 2.25) | 27.2*** | [3.7] | 24.6*** | [3.6] | 11.9*** | [3.0] | 11.4*** | [3.2] |
| [2.25, 2.75) | 41.3*** | [6.4] | 33.9*** | [5.8] | 26.0*** | [5.3] | 23.2*** | [5.5] |
| ≥ 2.75 | 93.4*** | [13.3] | 85.4*** | [11.6] | 50.5*** | [7.2] | 47.1*** | [7.6] |
| Const | 7.5*** | [1.5] | 8.6*** | [1.5] | 0.5 | [0.8] | 0.8 | [0.8] |
| Month FEs? | No | | Yes | | No | | Yes | |
| Adj. R2 | 0.22 | | 0.61 | | 0.24 | | 0.38 | |
| Obs. | 1532 | | 1532 | | 1151 | | 1151 | |
| Dates | 199601.201012 | | 199601.201012 | | 199601.200707 | | 199601.200707 | |

Table 3: Cross section of OAS^Q on pass-throughs. Coefficient estimates from OLS regression of the OAS^Q from our model on different moneyiness level bins either including or excluding time fixed effects. Newey-West standard errors (6 lags) in brackets. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

| | (1) | (2) | (3) | (4) |
|---------------|---------------|---------------|---------------|---------------|
| < -1.25 | 1.5 [3.8] | -1.3 [1.5] | -1.8 [1.5] | -1.5 [1.7] |
| [-1.25, -.75) | -0.2 [2.1] | -2.7** [1.2] | -2.9** [1.3] | -3.3** [1.3] |
| [-.75, -.25) | -1.4 [1.3] | -2.3** [0.9] | -1.2 [1.0] | -2.5*** [0.9] |
| [.25, .75) | -2.3*** [0.7] | -2.5*** [0.8] | -1.0 [0.8] | -1.5** [0.8] |
| [.75, 1.25) | -5.2*** [1.6] | -4.0*** [1.5] | -3.6** [1.4] | -4.1*** [1.5] |
| [1.25, 1.75) | -3.3 [2.5] | -1.4 [2.4] | -4.6* [2.3] | -4.9* [2.6] |
| [1.75, 2.25) | -3.1 [4.6] | 2.0 [3.8] | -9.7** [4.4] | -4.4 [4.1] |
| ≥ 2.25 | 6.1 [6.9] | 16.5*** [6.3] | 9.1 [8.6] | 15.5* [8.1] |
| Const | 13.8*** [1.6] | 13.1*** [0.9] | 7.9*** [1.1] | 7.9*** [0.8] |
| Month FEs? | No | Yes | No | Yes |
| Adj. | -0.00 | 0.73 | 0.02 | 0.52 |
| Obs. | 1005 | 1005 | 796 | 796 |
| Dates | 199501.201012 | 199501.201012 | 199501.200707 | 199501.200707 |

Table 4: Cross section of $OAS^P - OAS^Q$ on pass-throughs. Coefficient estimates from OLS regression of the prepayment-risk component in the OAS from our model on different moneyiness level bins either including or excluding time fixed effects. Newey-West standard errors (6 lags) in brackets. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

| | (1) | (2) | (3) | (4) |
|---------------|---------------|---------------|---------------|---------------|
| < -1.25 | 5.4*** [1.9] | 6.8*** [2.2] | 2.3 [1.7] | 3.3* [2.0] |
| [-1.25, -.75) | 2.9*** [0.9] | 5.2*** [1.2] | 0.9 [0.8] | 3.2*** [1.1] |
| [-.75, -.25) | -1.0*** [0.4] | 0.7 [0.7] | -1.8*** [0.3] | -0.0 [0.7] |
| [.25, .75) | 4.9*** [0.4] | 4.1*** [0.5] | 5.1*** [0.4] | 4.5*** [0.5] |
| [.75, 1.25) | 13.3*** [1.0] | 12.4*** [1.1] | 13.5*** [1.1] | 12.8*** [1.3] |
| [1.25, 1.75) | 22.1*** [1.5] | 20.7*** [1.7] | 22.3*** [1.7] | 21.2*** [1.9] |
| [1.75, 2.25) | 26.6*** [2.7] | 23.1*** [2.7] | 26.5*** [3.5] | 23.3*** [3.5] |
| ≥ 2.25 | 34.2*** [5.0] | 27.5*** [4.3] | 30.2*** [6.1] | 25.6*** [5.1] |
| Const | -1.4*** [0.2] | -1.0 [0.7] | -1.5*** [0.3] | -1.2* [0.7] |
| Month FEs? | No | Yes | No | Yes |
| Adj. R2 | 0.42 | 0.59 | 0.42 | 0.58 |
| Obs. | 1005 | 1005 | 796 | 796 |
| Dates | 199501.201012 | 199501.201012 | 199501.200707 | 199501.200707 |

Table 5: Time series regressions on pass-throughs (from stripped MBS) Coefficient estimates from OLS regression of spreads reported in the top row of each panel on the Aaa-Treasury spread, the Baa-Aaa spread, the 10-year to 3-month slope of the Treasury curve, the 2-year into 10-year swaption implied volatility, MBS issuance to assets of brokers and dealers, average moneyiness in the MBS universe squared and spreads on agency debt to swaps. All regressors are standardized to have zero mean and unit standard deviation. Newey-West standard errors (6 lags) in brackets. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Panel (a)

| | (1) OAS | (2) ZVS | (3) OAS | (4) ZVS |
|---------------|------------------|------------------|------------------|------------------|
| Aaa - Treas | 3.1* [1.9] | 5.7 [3.6] | 2.3 [3.2] | 5.4* [3.1] |
| Baa - Aaa | 15.7*** [3.3] | 11.3*** [3.2] | 10.5* [2.3] | 4.0 [6.8] |
| Treas Slope | 2.2 [2.2] | 0.8 [2.3] | 1.9 [4.1] | -1.3 [3.0] |
| Swaption Vol. | 1.6 [4.3] | 16.9*** [4.1] | 9.1* [4.8] | 33.0*** [5.7] |
| Const | 17.2*** [2.2] | 87.7*** [3.0] | 17.9*** [2.2] | 91.9*** [3.4] |
| Adj. R2 | 0.62 | 0.72 | 0.43 | 0.60 |
| Obs. | 192 | 192 | 151 | 151 |
| Dates | 199501.201012 | 199501.201012 | 199501.200707 | 199501.200707 |

Panel (b)

| | (1) OAS | (2) OAS ^Q | (3) OAS - OAS ^Q | (4) OAS | (5) OAS ^Q | (6) OAS - OAS ^Q |
|------------------------------|------------------|-------------------------|-------------------------------|------------------|-------------------------|-------------------------------|
| Baa - Aaa | 14.2*** [2.7] | 11.7*** [3.0] | 2.5*** [0.7] | 11.9*** [4.0] | 10.1* [5.2] | 1.8 [2.5] |
| MBS Issuance / BD Equity | 6.7*** [1.1] | 5.1*** [1.2] | 1.6** [0.8] | 6.1*** [1.3] | 3.8* [2.1] | 2.2 [1.4] |
| Mean Moneyiness ² | 2.2 [1.9] | -4.6** [2.0] | 6.8*** [1.0] | 4.5*** [1.6] | -1.3 [2.0] | 5.8*** [1.4] |
| Agency Debt Spreads | 6.9*** [2.1] | 8.0*** [2.3] | -1.0 [1.1] | 8.1*** [2.0] | 8.9*** [2.3] | -0.8 [1.3] |
| Const | 17.2*** [1.7] | 11.8*** [1.9] | 5.4*** [0.8] | 15.7*** [1.4] | 10.8*** [1.7] | 4.8*** [1.2] |
| Adj. R2 | 0.71 | 0.63 | 0.57 | 0.68 | 0.50 | 0.46 |
| Obs. | 192 | 192 | 192 | 151 | 151 | 151 |
| Dates | 199501.201012 | 199501.201012 | 199501.201012 | 199501.200707 | 199501.200707 | 199501.200707 |

Appendix

A MBS Cash Flows

This Appendix provides detail on the calculation of cash flows for an MBS, which are used to compute mortgage spreads as described in Section 2. Consider a fixed-rate MBS with an original balance of \$1, and let θ_t be the “factor,” or remaining balance relative to origination, at date t . In level-payment fixed-rate mortgages, the principal is repaid gradually rather than with a bullet payment at maturity and the borrower makes fixed payments inclusive of interest and principal every month. Denote the loan maturity measured in months by T (at the pool level, this is referred to as weighted average maturity, or WAM). Let k be the monthly installment from the borrower to the servicer, w the interest rate on the loan (or weighted average coupon, WAC, at the pool level), and c the coupon paid to investors. The difference between the loan and coupon rates is earned by servicers, s , or by the guaranteeing agency, g : $s + g = c - w$. To compute the fixed payment k note that, net of this payment, the loan balance absent any prepayment, denoted $\tilde{\theta}_t$ grows at rate $(1 + w)$, or:

$$\tilde{\theta}_t = (1 + w) \tilde{\theta}_{t-1} - k. \quad (\text{A.1})$$

Solving for $\tilde{\theta}_T = 0$, it then follows that $k = \left(\frac{w(1+w)^T}{(1+w)^T - 1} \right)$. The evolution of the loan balance θ_t including early prepayment generalizes equation (A.1) to take into account prepayments. After accounting for loan amortization and unscheduled principal payments, the factor evolves according to:

$$\theta_t = (1 - \text{SMM}_{t-1})(1 + w)\theta_{t-1} - k\hat{\theta}_t, \quad (\text{A.2})$$

where w is the interest rate on the loan (or weighted average coupon, WAC) and k is the constant monthly payment composed of the scheduled principal and interest payments. SMM_t is the “single month mortality,” or the fraction of the remaining balance that was prepaid in month t due to unscheduled principal payments, and $\hat{\theta}_t$ is the cumulated fraction of unit principal that has not prepaid since the inception of the mortgage, $\hat{\theta}_t = \prod_{s=0}^{t-1} (1 - \text{SMM}_s)$. The prepayment speed is often reported in annualized terms, known as the “conditional prepayment rate” or $\text{CPR}_t = 1 - (1 - \text{SMM}_t)^{12}$. Given prepayment rates, cash flows passed through to investors per unit of principal are:

$$X_t = (\theta_{t-1} - \theta_t) + c\theta_{t-1}, \quad (\text{A.3})$$

where the principal payment is equal to the decline in principal $(\theta_{t-1} - \theta_t)$ and the coupon payment from the borrower to the investor net of the servicing and agency guarantee fees is $c\theta_{t-1}$.

MBS cash flows shown in equation (A.3) are obtained from the path of θ_t by noting that the scheduled payment $(\theta_{t-1} - \theta_t)$ is equal to the total of the scheduled component $(k\hat{\theta}_t - w\theta_{t-1})$ and the unscheduled one $(\text{SMM}_{t-1}(1 + w)\theta_{t-1})$. Finally, borrowers pay $w\theta_{t-1}$ interest to servicers, which pass through the payments to investors after keeping a servicing stream equal to $(c - w)\theta_{t-1}$ net of a fraction that is used to pay the guarantee fee to the agency.

B Data

B.1 TBA sample and data-quality filters

The sample spans 1996 to 2010, reflecting limited data availability on TBAs, which we use to characterize the facts in this section, prior to 1996, and a limited liquidity in IO/PO strips, which we use later in the paper to decompose the OAS, post 2010. For all but one dealer, we have both ZVS and OAS (for the remaining one just OAS), but not necessarily for all the same coupons on each day. In addition, some of the dealers enter our data only after 1996, and we do not have any ZVS before 1998. We clean each dealer's data to prevent spreads from being influenced by stale prices. To do so, we check whether a price for a coupon is unchanged relative to the previous day. If it is, and if the 10-year Treasury yield changed by 3 basis points or more on the same day (so we expect MBS prices to change), we drop the price and the corresponding OAS and ZVS. If the price is not constant, but had been constant more than twice in the same calendar month on days when the Treasury yield moves, we similarly drop it.

B.2 Stripped MBS data-quality filters

We start with daily price quotes from a large dealer for the period 1995 to 2010, and then clean these data using the following steps:

1. Remove/correct obvious outliers (such as prices of 0 or a few instances where IO and PO prices were inverted).
2. Remove prices that are stale (defined as a price that does not change from previous day despite a change in the 10-year yield of more than 3 basis points). In case of smaller yield changes, we check the previous 10 days and remove a price if there were more than two instances of stale prices on that security over that period.
3. For a subsample of trusts and months (starting in June 1999), we also have price quotes from two additional dealers. When available, we compare these prices (their average if both are available) to the price quoted by our dealer. When they are more than 5% apart, or if the overall range of price quotes is larger than 0.1 times the average price, we do not use our price quote in the analysis. This applies to about 10% of our price quotes.
4. Only retain trusts for which we have both the IO and PO strips, and which we can link to data on the underlying pool of mortgages (from eMBS). This restriction eliminates IO strips backed by excess servicing rights, for instance.
5. Only retain trusts for which the price on the recombined pass-through ($= P_{PO} + P_{IO}$) is within \$2 of the TBA price of the corresponding coupon. (We also drop trusts if on that day we do not have a clean TBA price for the corresponding coupon.)

6. Only retain trusts with a factor (= current face value divided by issuance amount) of more than 5%.
7. Only retain trusts that we can match to a Bloomberg prepayment survey with the same coupon and absolute differences in WAC and WAM smaller than 0.3 percentage points and 60 months, respectively. (This affects almost exclusively observations before 2003, as we don't have individual vintages in the survey in the early years.)

Following these steps, the sample includes 3713 trust-month observations, or about 19 per month. The year with the lowest number of observations is 1999, where we have an average of 10 trusts per month, while after 2005 we have at least 20 trusts in all but one month.

C Additional Details on Model

In this Appendix, we derive the formulas for OAS and ZVS on the pass-through security used in Section 3, as well as on the IO and PO strips. Recall that, in each instant of time dt , the investor in the pass-through security on pool j receives $c_j - d\theta_{jt}$ per dollar of face value. Thus, the price of one unit of the pass-through satisfies

$$P_{PT,t}^j = \mathbb{E}_t \left[\int_0^{+\infty} \frac{M_{t+s}}{M_t} (c_j + s_{js}) ds \right] = \mathbb{E}_t^Q \left[\int_0^{+\infty} e^{-\int_0^s (r_u + s_{ju}) du} (c_j + s_{js}) ds \right],$$

where Q is the risk-neutral measure associated with the pricing kernel M . Assume that the short rate r_t evolves according to

$$dr_t = \mu_{rt} dt + \sigma_r dZ_{rt},$$

where Z_{rt} is a standard Brownian motion, independent of the shocks to the prepayment function parameters, $Z_{\gamma t}$. Then, applying the Feynman-Kac theorem, we can represent the price of the pass-through security as the solution to

$$\begin{aligned} r_t P_{PT,t}^j = (c_j + s_{jt}) - s_{jt} P_{PT,t}^j - \mu_t \pi_{lt} \alpha_j P_{PT,t}^j + \frac{\partial P_{PT,t}^j}{\partial r_t} (\mu_{rt} + \sigma_r \pi_{rt}) + \frac{1}{2} \frac{\partial^2 P_{PT,t}^j}{\partial r_t^2} \sigma_r^2 \\ + \frac{\partial P_{PT,t}^j}{\partial \gamma_t'} (\mu_\gamma + \sigma_\gamma \pi_{\gamma t}) + \frac{1}{2} \text{tr} \left(\frac{\partial^2 P_{PT,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right), \quad (\text{C.1}) \end{aligned}$$

where π_{rt} is the price of risk associated with innovations to the short rate Z_{rt} .

The zero-volatility spread (ZVS) is computed using the risk-neutral mean path of the interest rates, but ignoring variation around that path and non-interest rate sources of risk. More formally,

the ZVS on the pass-through solves

$$(r_t + ZVS_{jt}) P_{PT,t}^j = (c_j + s_{jt}) - s_{jt} P_{PT,t}^j - \mu_t \alpha_j P_{PT,t}^j + \frac{\partial P_{PT,t}^j}{\partial r_t} (\mu_{rt} + \sigma_r \pi_{rt}) + \frac{\partial P_{PT,t}^j}{\partial \gamma_t'} \mu_\gamma. \quad (\text{C.2})$$

Comparing (C.1) and (C.2), we see that the ZVS on the pass-through is given by

$$ZVS_{jt} = -\frac{1}{P_{PT,t}^j} \frac{\partial^2 P_{PT,t}^j}{\partial r_t^2} \frac{\sigma_r^2}{2} - \frac{1}{2} \frac{1}{P_{PT,t}^j} \text{tr} \left(\frac{\partial^2 P_{PT,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right) - \pi_{\gamma t}' \sigma_\gamma \frac{1}{P_{PT,t}^j} \frac{\partial P_{PT,t}^j}{\partial \gamma_t} + \alpha_j \mu_t (\pi_{lt} - 1).$$

The option-adjusted spread (OAS), on the other hand, recognizes that interest rates can deviate from the mean paths and thus solves

$$(r_t + OAS_{jt}) P_{PT,t}^j = (c_j + s_{jt}) - s_{jt} P_{PT,t}^j - \mu_t \alpha_j P_{PT,t}^j + \frac{\partial P_{PT,t}^j}{\partial r_t} (\mu_{rt} + \sigma_r \pi_{rt}) + \frac{\partial^2 P_{PT,t}^j}{\partial r_t^2} \frac{\sigma_r^2}{2} + \frac{\partial P_{PT,t}^j}{\partial \gamma_t'} \mu_\gamma + \frac{1}{2} \text{tr} \left(\frac{\partial^2 P_{PT,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right). \quad (\text{C.3})$$

Comparing (C.1) and (C.3), we see that the OAS on the pass-through is given by

$$OAS_{jt} = -\pi_{\gamma t}' \sigma_\gamma \frac{1}{P_{PT,t}^j} \frac{\partial P_{PT,t}^j}{\partial \gamma_t} + \alpha_j \mu_t (\pi_{lt} - 1).$$

Thus, the OAS is the risk premium paid to the MBS investors for holding non-interest rate risk. Comparing the ZVS and the OAS on the pass-through, we see that the option cost is given by

$$ZVS_{jt} - OAS_{jt} = -\frac{1}{P_{PT,t}^j} \frac{\partial^2 P_{PT,t}^j}{\partial r_t^2} \frac{\sigma_r^2}{2} - \frac{1}{2} \frac{1}{P_{PT,t}^j} \text{tr} \left(\frac{\partial^2 P_{PT,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right) \approx -\frac{1}{P_{PT,t}^j} \frac{\partial^2 P_{PT,t}^j}{\partial r_t^2} \frac{\sigma_r^2}{2}$$

for small variance of the innovations to prepayment function parameters.

Finally, we compute OAS^Q taking into account compensation for prepayment model risk, so that the OAS^Q solves

$$(r_t + OAS_{jt}^Q) P_{PT,t}^j = (c_j + s_{jt}) - s_{jt} P_{PT,t}^j - \mu_t \alpha_j P_{PT,t}^j + \frac{\partial P_{PT,t}^j}{\partial r_t} (\mu_{rt} + \sigma_r \pi_{rt}) + \frac{\partial^2 P_{PT,t}^j}{\partial r_t^2} \frac{\sigma_r^2}{2} + \frac{\partial P_{PT,t}^j}{\partial \gamma_t'} (\mu_\gamma + \sigma_\gamma \pi_{\gamma t}) + \frac{1}{2} \text{tr} \left(\frac{\partial^2 P_{PT,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right). \quad (\text{C.4})$$

Comparing (C.1) and (C.4), we see that the OAS^Q on the pass-through is given by

$$OAS_{jt}^Q = \alpha_j \mu_t (\pi_{lt} - 1).$$

We can compute the OAS, OAS^Q and ZVS on stripped securities in a similar fashion. In each instant of time dt , an investor holding the IO strip on pool j receives the coupon payments c_j while an investor holding the PO strip receives the principal payments $-d\theta_{jt}$. Then, similarly to (C.1), the price $P_{IO,t}^j$ of the IO strip is the solution to

$$r_t P_{IO,t}^j = c_j - s_{jt} P_{IO,t}^j - \mu_t \pi_{lt} \alpha_j P_{IO,t}^j + \frac{\partial P_{IO,t}^j}{\partial r_t} (\mu_{rt} + \sigma_r \pi_{rt}) + \frac{1}{2} \frac{\partial^2 P_{IO,t}^j}{\partial r_t^2} \sigma_r^2 + \frac{\partial P_{IO,t}^j}{\partial \gamma_t'} (\mu_\gamma + \sigma_\gamma \pi_{\gamma t}) + \frac{1}{2} \text{tr} \left(\frac{\partial^2 P_{IO,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right), \quad (\text{C.5})$$

and the price $P_{PO,t}^j$ of the PO strip is the solution to

$$r_t P_{PO,t}^j = s_{jt} - s_{jt} P_{PO,t}^j - \mu_t \pi_{lt} \alpha_j P_{PO,t}^j + \frac{\partial P_{PO,t}^j}{\partial r_t} (\mu_{rt} + \sigma_r \pi_{rt}) + \frac{1}{2} \frac{\partial^2 P_{PO,t}^j}{\partial r_t^2} \sigma_r^2 + \frac{\partial P_{PO,t}^j}{\partial \gamma_t'} (\mu_\gamma + \sigma_\gamma \pi_{\gamma t}) + \frac{1}{2} \text{tr} \left(\frac{\partial^2 P_{PO,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right). \quad (\text{C.6})$$

The ZVS, OAS and OAS^Q on the stripped securities are defined analogously to (C.2)-(C.4). Thus, the ZVS, OAS and OAS^Q on the IO strip are given, respectively, by

$$\begin{aligned} ZVS_{jt,IO} &= -\frac{1}{P_{IO,t}^j} \frac{\partial^2 P_{IO,t}^j}{\partial r_t^2} \frac{\sigma_r^2}{2} - \frac{1}{2} \frac{1}{P_{IO,t}^j} \text{tr} \left(\frac{\partial^2 P_{IO,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right) - \pi_{\gamma t}' \sigma_\gamma \frac{1}{P_{IO,t}^j} \frac{\partial P_{IO,t}^j}{\partial \gamma_t} + \alpha_j \mu_t (\pi_{lt} - 1) \\ OAS_{jt,IO} &= -\pi_{\gamma t}' \sigma_\gamma \frac{1}{P_{IO,t}^j} \frac{\partial P_{IO,t}^j}{\partial \gamma_t} + \alpha_j \mu_t (\pi_{lt} - 1) \\ OAS_{jt,IO}^Q &= \alpha_j \mu_t (\pi_{lt} - 1). \end{aligned}$$

Similarly, the ZVS, OAS and OAS^Q on the PO strip are given, respectively, by

$$\begin{aligned} ZVS_{jt,PO} &= -\frac{1}{P_{PO,t}^j} \frac{\partial^2 P_{PO,t}^j}{\partial r_t^2} \frac{\sigma_r^2}{2} - \frac{1}{2} \frac{1}{P_{PO,t}^j} \text{tr} \left(\frac{\partial^2 P_{PO,t}^j}{\partial \gamma_t \partial \gamma_t'} \sigma_\gamma \sigma_\gamma' \right) - \pi_{\gamma t}' \sigma_\gamma \frac{1}{P_{PO,t}^j} \frac{\partial P_{PO,t}^j}{\partial \gamma_t} + \alpha_j \mu_t (\pi_{lt} - 1) \\ OAS_{jt,PO} &= -\pi_{\gamma t}' \sigma_\gamma \frac{1}{P_{PO,t}^j} \frac{\partial P_{PO,t}^j}{\partial \gamma_t} + \alpha_j \mu_t (\pi_{lt} - 1) \\ OAS_{jt,PO}^Q &= \alpha_j \mu_t (\pi_{lt} - 1). \end{aligned}$$

Thus, when the stripped MBS have equal exposure to liquidity risk, the prepayment risk-neutral OAS, OAS^Q , is equal for an IO and PO pair, as well as the corresponding pass-through.

D Pricing Model Details

D.1 Interest Rate Model

We assume that swap rates follow a three-factor [Heath, Jarrow, and Morton \(1992\)](#) (HJM) model. Let $f(t, T)$ denote the time t instantaneous forward interest rate for risk-free borrowing and lending at time T . We model the forward rate dynamics under the (interest rate) risk-neutral measure as

$$df(t, T) = \mu_f(t, T) dt + \sum_{i=1}^3 \sigma_{f,i}(t, T) dW_{i,t}^Q,$$

where W_{it}^Q are independent standard Weiner processes under the risk-neutral measure Q , and, under no arbitrage, the expected change in the forward rate is given by

$$\mu_f(t, T) = \sum_{i=1}^3 \sigma_{f,i}(t, T) \int_t^T \sigma_{f,i}(t, u) du.$$

Thus, the risk-neutral dynamics of the instantaneous forward rate are completely determined by the initial forward rate curve and the forward rate volatility functions, $\sigma_{f,i}(t, T)$. Similarly to [Trolle and Schwartz \(2009\)](#), we assume that the volatility function of each factor $\sigma_{f,i}(t, T)$ is

$$\sigma_{f,i}(t, T) = (\alpha_{0,i} + \alpha_{1,i}(T - t)) e^{-\gamma_i(T-t)}. \quad (D.1)$$

This specification has the advantage of allowing for a wide range of shocks to the forward rate curve while ensuring that the forward rate model above is Markovian.

[Trolle and Schwartz \(2009\)](#) show that, setting the volatility of the forward rates to be as in (D.1), the time t price of a zero-coupon bond maturing at time T , $P(t, T)$, is given by

$$P(t, T) \equiv \exp \left\{ - \int_t^T f(t, u) du \right\} = \frac{P(0, T)}{P(0, t)} \exp \left\{ \sum_{i=1}^3 B_{x_i}(T - t) x_{it} + \sum_{i=1}^3 \sum_{j=1}^6 B_{\phi_{ji}}(T - t) \phi_{ji,t} \right\},$$

where the state variables $\{x_{it}, \phi_{ji,t}\}$ follow

$$\begin{aligned} dx_{it} &= -\gamma_i x_{it} dt + dW_{it}^Q \\ d\phi_{1i,t} &= (x_{it} - \gamma_i \phi_{1i,t}) dt \\ d\phi_{2i,t} &= (1 - \gamma_i \phi_{2i,t}) dt \\ d\phi_{3i,t} &= (1 - 2\gamma_i \phi_{3i,t}) dt \\ d\phi_{4i,t} &= (\phi_{2i,t} - \gamma_i \phi_{4i,t}) dt \\ d\phi_{5i,t} &= (\phi_{3i,t} - 2\gamma_i \phi_{5i,t}) dt \\ d\phi_{6i,t} &= (2\phi_{5i,t} - 2\gamma_i \phi_{6i,t}) dt. \end{aligned}$$

The coefficients $\{B_{x_i}, B_{\phi_{ji}}\}$ are functions of the parameters of the volatility function and the time to maturity $\tau = T - t$, and are given by

$$\begin{aligned}
B_{x_i}(\tau) &= \frac{\alpha_{1i}}{\gamma_i} \left(\left(\frac{1}{\gamma_i} + \frac{\alpha_{0i}}{\alpha_{1i}} \right) (e^{-\gamma_i \tau} - 1) + \tau e^{-\gamma_i \tau} \right) \\
B_{\phi_{1i}}(\tau) &= \frac{\alpha_{1i}}{\gamma_i} (e^{-\gamma_i \tau} - 1) \\
B_{\phi_{2i}}(\tau) &= \left(\frac{\alpha_{1i}}{\gamma_i} \right)^2 \left(\frac{1}{\gamma_i} + \frac{\alpha_{0i}}{\alpha_{1i}} \right) \left(\left(\frac{1}{\gamma_i} + \frac{\alpha_{0i}}{\alpha_{1i}} \right) (e^{-\gamma_i \tau} - 1) + \tau e^{-\gamma_i \tau} \right) \\
B_{\phi_{3i}}(\tau) &= -\frac{\alpha_{1i}}{\gamma_i^2} \left(\left(\frac{\alpha_{1i}}{2\gamma_i^2} + \frac{\alpha_{0i}}{\gamma_i} + \frac{\alpha_{0i}^2}{2\alpha_{1i}} \right) (e^{-2\gamma_i \tau} - 1) + \left(\frac{\alpha_{1i}}{\gamma_i} + \alpha_{0i} \right) \tau e^{-2\gamma_i \tau} + \frac{\alpha_{1i}}{2} \tau^2 e^{-2\gamma_i \tau} \right) \\
B_{\phi_{4i}}(\tau) &= \left(\frac{\alpha_{1i}}{\gamma_i} \right)^2 \left(\frac{1}{\gamma_i} + \frac{\alpha_{0i}}{\alpha_{1i}} \right) (e^{-\gamma_i \tau} - 1) \\
B_{\phi_{5i}}(\tau) &= -\frac{\alpha_{1i}}{\gamma_i^2} \left(\left(\frac{\alpha_{1i}}{\gamma_i} + \alpha_{0i} \right) (e^{-2\gamma_i \tau} - 1) + \alpha_{1i} \tau e^{-2\gamma_i \tau} \right) \\
B_{\phi_{6i}}(\tau) &= -\frac{1}{2} \left(\frac{\alpha_{1i}}{\gamma_i} \right)^2 (e^{-2\gamma_i \tau} - 1).
\end{aligned}$$

Consider now a period of length ν and a set of dates $T_j = t + \nu j$, $j = 1, \dots, n$. The time t swap rate for the period t to T_n , with fixed-leg payments at dates T_1, \dots, T_n is given by

$$S(t, T_n) = \frac{1 - P(t, T_n)}{\nu \sum_{j=1}^n P(t, T_j)},$$

and the time t forward swap rate for the period T_m to T_n , and fixed-leg payments at dates T_{m+1}, \dots, T_n by

$$S(t, T_n) = \frac{P(t, T_m) - P(t, T_n)}{\nu \sum_{j=m+1}^n P(t, T_j)}.$$

Applying Ito's lemma to the time u forward swap rate between T_m and T_n , and switching to the forward measure \mathbb{Q}^{T_m, T_n} under which forward swap rates are martingales (see e.g. [Jamshidian, 1997](#)), we obtain

$$dS(u, T_m, T_n) = \sum_{i=1}^3 \sum_{j=m}^n \zeta_j(u) B_{x_i}(T_j - u) dW_{iu}^{\mathbb{Q}^{T_m, T_n}},$$

where

$$\zeta_j(u) = \begin{cases} \frac{P(u, T_m)}{v \sum_{j=m+1}^n P(u, T_j)} & \text{if } j = m; \\ -\nu S(u, T_m, T_n) \frac{P(u, T_j)}{v \sum_{j=m+1}^n P(u, T_j)} & \text{if } j = m+1, \dots, n-1 \\ -(1 + \nu S(u, T_m, T_n)) \frac{P(u, T_n)}{v \sum_{j=m+1}^n P(u, T_j)} & \text{if } j = n. \end{cases}$$

Notice that, since the $\zeta_j(u)$ terms are stochastic, the forward swap rates are not normally distributed. We can, however, approximate $\zeta_j(u)$ by their time t expected values, which are their time t values since these terms are martingales under the forward-swap measure. Thus, given date t information, the swap rate between dates T_m and T_n is (approximately) normally distributed

$$S(T_m, T_n) \sim \mathcal{N}\left(S(t, T_m, T_n), \sigma_N(t, T_m, T_n) \sqrt{T_m - t}\right),$$

where the volatility σ_N is given by

$$\sigma_N(t, T_m, T_n) = \left(\frac{1}{T_m - t} \int_t^{T_m} \sum_{i=1}^N \left(\sum_{j=m}^n \zeta_j(t) B_{x_i}(T_j - u) \right)^2 du \right)^{\frac{1}{2}}.$$

D.2 Yield Curve Model

We closely follow the estimation of [Gürkaynak et al. \(2007\)](#) on Treasury yields using quotes on par swap yields with maturities between 1 and 40 years. We assume that instantaneous forward rates n -years hence are a function of six parameters:

$$f_t(n, 0) = \beta_0 + \beta_1 \exp(-n/\tau_1) + \beta_2 (n/\tau_1) \exp(-n/\tau_1) + \beta_3 (n/\tau_2) \exp(-n/\tau_2). \quad (\text{D.2})$$

We fit these parameters at month end by minimizing the sum of squared deviations between actual and predicted swap prices weighted by their inverse duration, which is approximately equal to minimizing the sum of squared yield deviations.

D.3 Prepayment Model Detail

As described in the main text, we begin by constructing a panel of monthly dealer prepayment forecasts by coupon-vintage using data from eMBS and Bloomberg LP. Specifically, we match pool characteristics from eMBS (WAC, WALA, WAM) to corresponding prepayment forecasts from Bloomberg. For each coupon until May 2003, and for each coupon-vintage from May 2003 onward, dealers report a prepayment forecast for each of the nine interest rate scenarios, as well as a WAC and WAM. To obtain additional pool characteristics, for the later sample, each survey is matched to its corresponding pool in eMBS. For the earlier sample, we match the survey to the vintage of the same coupon in eMBS with the minimum Mahalanobis distance based on WAC and WAM

from the dealer’s response. We only use securities that have a remaining principal balance in eMBS of more than \$1 million.

Dealers update their forecasts on different dates, so we use the most recent response as of the end of the month for each dealer (excluding dealers who did not update their response during that month), keeping only those securities in a month for which at least two dealers responded. Because we are interested in extracting prepayment model parameters that capture, for instance, the expectations of the rate-sensitivity of a security, we match each dealer’s response to the swap rate of the day before that dealer’s survey response was updated.

The prepayment forecasts in Bloomberg are reported in “PSA” terms, which can be translated into monthly CPRs using the following formula:

$$\text{CPR}_\tau = \text{PSA}/100 * \min(.2 * \text{WALA}_\tau, 6) \text{ for } t \leq \tau \leq \text{WAM} \quad (\text{D.3})$$

Thus, two securities with the same PSA forecast but of different ages (WALAs) will have different “average” CPRs if at least one of the securities is unseasoned. Because we would like to capture the prepayment speed forecast of the dealers with a single number for ease of estimation, we use the PSA forecast and the WALA¹ to compute the WAL (weighted average life), and thus the WAL-implied long-run CPR, defined as the constant monthly CPR that generates the WAL.

Specifically, we convert the monthly CPRs generated using equation D.3 to SMMs and compute the implied cash flows as in Section 2. The WAL is then defined as:

$$\text{WAL}_t = \frac{\sum_{j=t}^{\text{WAM}} j \text{CF}_j}{\sum_{j=t}^{\text{WAM}} \text{CF}_j}. \quad (\text{D.4})$$

This gives us one long-run CPR forecast for each scenario per vintage per dealer. The nine different scenarios give us information about the expected rate sensitivity of the security. A common way to model this rate-sensitivity is through the use of an “S curve” as mentioned in the main text. Such a curve captures the observed behavior that prepayments are low for securities that are “out-of-the-money,” i.e., the incentive to refinance is negative, and are mostly due to turnover and, to a lesser extent, cash-out refinancing or defaults. As a pool moves in-the-money (the refinancing incentive becomes positive) the refinancing component becomes a more important driver of prepayments, but at a declining rate: there is an incentive region in which prepayments are highly sensitive to changes in the interest rate (typically somewhere in the incentive region of 50-150 basis points) while beyond that, there is little sensitivity to further decreases in the available rate.

We convert our nine long-run CPRs into SMMs and fit the following S curve for each dealer

¹Since dealers don’t actually report WALAs, we infer the WALA for a particular dealer’s response by subtracting that dealer’s surveyed WAM from the average sum of the WAM and WALA in eMBS.

for a vintage using nonlinear least squares:

$$\text{SMM}_i^{LR} = b_1 + b_4 \frac{\exp(b_2 + b_3 * \text{INC}_i)}{1 + \exp(b_2 + b_3 \text{INC}_i)} \text{ for } i = 1, 2, \dots, 9 \quad (\text{D.5})$$

where $b_1, b_4 \in [0, 1]$ and $b_1 + b_4 \leq 1$ (these constraints ensure that the function is bounded by 0 and 1). Here, INC_i is defined as the difference between the dealer's observed swap rate and WAC in scenario i .

Estimating an S curve for each dealer allows us to “average” these dealer responses despite the fact that often the surveys were updated on different days and thus refer to slightly different interest rate scenarios. We take this average by averaging fitted dealer SMMs at 50 basis point intervals between -300 and 300 basis points, with the 0-scenario corresponding to the average 0-scenario across dealers.

Finally, because cash flows, and thus the OAS, depend on not just the average long-run prepayment rate, but also the time pattern of prepayments, we fit a series of monthly SMMs in the form of equations 4.1 and 4.2 to the dealer-averaged long-run CPR forecasts. As discussed in the main text, this functional form creates the “burnout effect” of prepayments. However, because the Bloomberg data provide no additional information as to the time pattern of prepayments, it is impossible to jointly identify $\chi_t, \kappa_1, \kappa_2$ for each security. We therefore assume that κ_1 and κ_2 are universal parameters and let χ_t vary across securities and time. To calibrate κ_1 and κ_2 , we exploit the fact that as $\text{INC} \rightarrow \infty$, $\text{SMM} \rightarrow b_1 + \chi\kappa_1 + (1 - \chi)\kappa_2$ (for $\text{WALA} > 30$). Thus, $b_1 + \kappa_1$ and $b_1 + \kappa_2$ represent the speeds that a seasoned pool would prepay at if it were deeply in the money and composed of only fast or only slow borrowers, respectively. We therefore estimate $\hat{\kappa}_1 = \kappa_1$ and $\hat{\kappa}_2 = \kappa_2$ by taking the 99th and 1st percentiles of survey SMMs (less an average b_1 , which is negligible) for the -300 basis point interest rate scenario among seasoned ITM securities in our sample. This yields $\hat{\kappa}_1 = 0.11$ and $\hat{\kappa}_2 = 0.014$.²

Given κ_1 and κ_2 , there are then four coefficients to be estimated for each security on each date: χ_t, b_1, b_2 , and b_3 . We fit these four coefficients using nonlinear least squares with the thirteen dealer-averaged long-run fitted CPRs. Because of its flexibility, this model is able to fit the long-run CPRs quite well; the MAE across securities is less than 0.2.

D.4 Monte Carlo Simulations

As discussed in Section 2, computing the OAS requires Monte Carlo simulations of swaps and discount rates. Along each simulation, we use the prepayment model to compute MBS cash flows. We take the OAS to be the constant spread to swaps that sets the average discounted value of cash flows along these paths equal to the market price. To construct these paths, we first simulate 1,000 paths of the three factors of the interest rate model using draws of the state variables described in Appendix D.1. We use antithetic variables as a variance reduction technique, giving us 2,000 paths in total.

²We have experimented with alternative calibrations, and obtained qualitatively similar results.