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AGENCY MBS AS SAFE ASSETS

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ABSTRACT

Measured as yield spreads against AAA corporate bonds, the convenience premium for agency MBS averaged 47 basis points between 1995 and 2021, about half of the long-term-Treasury convenience premium. Both the MBS convenience premium and the issuance amount vary negatively with the mortgage rate, which is consistent with a prepayment-driven demand channel. This negative dependence contrasts strikingly with the positive dependence of the MBS-repo convenience premium on interest rates, as implied by the "opportunity cost of money" hypothesis. The placing of agencies into conservatorship in 2008 and the introduction of the liquidity coverage ratio in 2013 affected the convenience premium significantly, which is consistent with the safety and regulatory-constraint channels of demand for MBS. Based on "structural" restrictions in standard models, the ratio of MBS to Treasury convenience premia pinpoints the time-varying MBS-specific demand empirically.

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1 Introduction

Liquid and safe assets serve as important liquidity reserves and stable stores of value; according to Gorton (2017), they "play a critical role in the economy and have implications for transactions and savings efficiency, financial crises, general aggregate macroeconomic activity, and monetary policy." But which assets serve as safe assets? The empirical literature so far has focused mainly on reserves at central banks and Treasury securities as public safe assets, and bank deposits, commercial paper, and repurchase agreements as private safe assets.[1] In this paper, we analyze the distinctive role of and economic channels for agency mortgage-backed securities (MBS)—those guaranteed by Fannie Mae, Freddie Mac, and Ginnie Mae—as long-term safe assets.

The agency MBS market is huge, with an outstanding balance of $11 trillion as of December 2021, according to the Securities Industry and Financial Markets Association (SIFMA); in comparison, the outstanding balances of Treasury securities, corporate bonds, and municipal bonds are $23, $10, and $4 trillion, respectively. Importantly, there is ample anecdotal evidence pertaining to the nature and role of agency MBS as safe assets. First, with principal balances essentially backed by the U.S. government, the safety of agency MBS is similar to that of Treasury securities. Second, in the liquidity coverage ratio (LCR) requirement of Basel III, agency MBS are an important component of "high-quality liquid assets (HQLA) that can be converted easily and immediately in private markets into cash" (Bank for International Settlements, 2013). As shown in Figure 1, the fraction of agency MBS in HQLA holdings by major banks is about half the fraction of Treasury securities as of 2021:Q4, much higher than the fraction of all other securities (about 0.3%).[2] Third, agency MBS are widely used as collateral for repo financing, which can conveniently cushion temporary liquidity shocks. Figure 1 shows that MBS account for 20% of the total tri-party repo collateral, again behind Treasury securities (75%) but greater than all others combined (4%).[3] Finally,

[1]The empirical literature on safe assets is vast; to name a few, Krishnamurthy and Vissing-Jorgensen (2012); Greenwood, Hanson, and Stein (2015); Nagel (2016); Sunderam (2014); Carlson, Duygan-Bump, Natalucci, Nelson, Ochoa, Stein, and den Heuvel (2016); Kacperczyk, Perignon, and Vuillemey (2021). The concept of a safe asset is, however, elusive (Caballero, Farhi, and Gourinchas, 2017); theoretical models have emphasized several economic channels, such as Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2015) on information sensitivity, and Farhi and Maggiori (2017) and He, Krishnamurthy, and Milbradt (2019) on coordination.

[2]According to the Federal Reserve's Flow of Funds reports, banks hold about $3.5 trillion of agency MBS (and agency debt). Other large holders include the Federal Reserve ($2.7 trillion), foreign investors ($1.3 trillion), mutual funds ($0.7 trillion), insurance companies ($0.5 trillion), pension funds ($0.4 trillion), and money market funds ($0.4 trillion).

[3]Therefore, in HQLA holdings and repo collateral volume, the fractions of agency MBS and Treasury

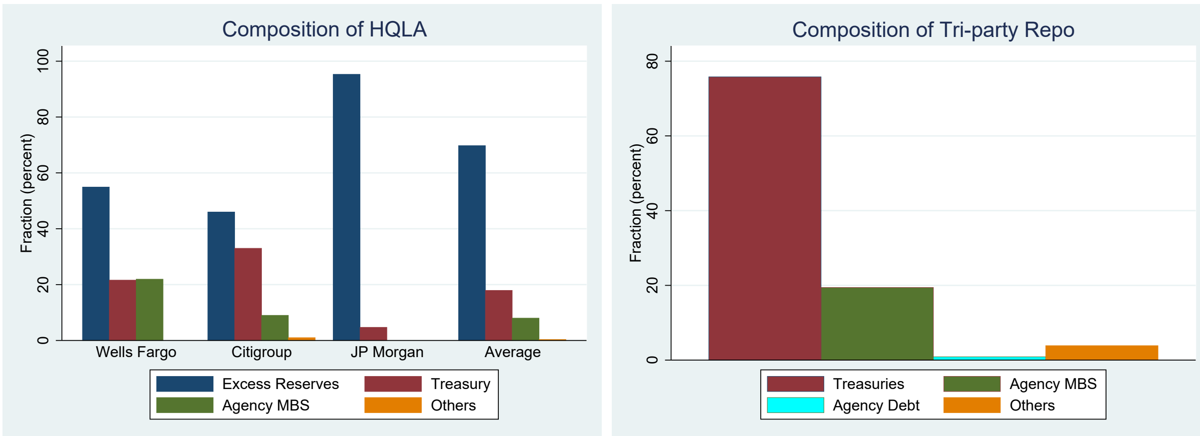

Figure 1: HQLA and Repo

The left panel reports the fraction of excess reserves, Treasury securities, agency MBS, and other securities (such as corporate and municipal bonds) of HQLA in 2021:Q4 for Citigroup, Wells Fargo, and JP Morgan, respectively, as well as the average across the three banks. The right panel reports the fraction of Treasury securities, agency MBS, agency debt, and other investment grade assets (including investment grade ABS, private-label CMO, and corporate bonds, as well as municipal bonds and money market instruments) that compose the outstanding balance of tri-party repo as of December 2021. Appendix C provides details.

MBS are a critical component of monetary policy operations, experiencing purchases by the Federal Reserve (Fed) during the 2008 financial crisis and the 2020 COVID-19 crisis, which has likely strengthened their safe-asset status.

Motivated by this anecdotal evidence, we analyze the economic channels associated with agency MBS as safe assets. We start our analysis in Section 2 by formulating an economic framework for the MBS convenience premium using the standard money-in-the-utility (MIU) approach (Krishnamurthy and Vissing-Jorgensen, 2012; Nagel, 2016) and also allowing the MBS supply to be endogenously determined in equilibrium (as in Sunderam 2014 who studies commercial paper); from here, we conduct our empirical analyses. What distinguishes our analyses from existing studies of safe assets is that we focus on demand for MBS *relative* to demand for other safe assets such as Treasury securities; these MBS-specific demand drivers include prepayments, principal safety, and regulatory constraint.

To conduct empirical tests of these MBS-specific demand drivers, we use AAA corporate bonds as the benchmark asset, following Krishnamurthy and Vissing-Jorgensen (2012),[4] and

securities are comparable to their relative outstanding amounts, while the fraction of corporate bonds, municipal bonds, asset-backed securities, and private-label MBS is negligible compared with their total outstanding balance (which is about $17 trillion combined).

[4]Through all our analyses, we follow Krishnamurthy and Vissing-Jorgensen (2012) and include the VIX and slope of the yield curve as controls for variations in the AAA yield due to corporate default. We also

measure the convenience premium of newly issued 30-year Fannie Mae MBS using the AAA-MBS yield spread.[5] Following the literature (Gabaix, Krishnamurthy, and Vigneron, 2007; Boyarchenko, Fuster, and Lucca, 2019; Song and Zhu, 2019), we adjust MBS yields regarding the value of prepayment options that U.S. mortgage borrowers have, based on prepayment models of MBS dealers. After further adjusting the AAA-MBS yield spread for duration mismatch between corporate bonds and MBS, we find that the monthly average of the MBS convenience premium is 47 basis points (bps) between 1995 and 2021, about half that of the long-term-Treasury convenience premium measured by the AAA-Treasury yield spread. Moreover, we use the monthly issuance amount as the supply measure, which averages about $18 billion. Note that MBS with varying coupon rates are issued at the same time (we take advantage of this panel structure in a later analysis); the aforementioned numbers represent the MBS with the highest issuance amount each month, often known as the "production-coupon" stack.[6]

Using these measures, our first set of main analyses focuses on prepayment-driven demand for MBS (in Section 3.2). Prepayment is a unique feature of MBS that makes the timing of cash flows to investors uncertain (Hayre and Young, 2004), and it is natural to conjecture that the prepayment incentive would negatively affect investors' demand for MBS relative to demand for other safe assets that are not subject to prepayment. One could micro-found this safe-asset demand for MBS on either prepayment modeling uncertainty (Hansen and Sargent, 2001), information asymmetry (Gorton and Pennacchi, 1990), or coordination issues arising from these two forces (He et al., 2019).

We measure variations in the prepayment incentive of production-coupon MBS using mortgage rate; a higher mortgage rate today indicates greater expected "moneyness" in the future when interest rate reverts to its long-run mean.[7] The hypothesis we will test, therefore, is whether a higher mortgage rate leads to weaker demand for MBS, and thus wider AAA-MBS yield spreads and smaller MBS issuance amounts. Indeed, monthly time-series

confirm our results by adjusting the AAA yield using the CDS spread of corporate bonds.

[5]Fannie Mae 30-year MBS are the largest across agencies and tenors: Fannie Mae MBS account for over 40% of all agency MBS outstanding, while 30-year MBS account for over 80% (Liu, Song, and Vickery, 2021).

[6]According to the SIFMA, the monthly issuance amount of agency MBS (across coupon, tenor, and agency) is $280 billion, comparable to that of Treasury securities ($390 billion) and larger than that of corporate bonds ($76 billion) and municipal bonds ($40 billion).

[7]The standard moneyness measure, defined as the difference between the underlying mortgage rate of the MBS and the prevailing mortgage rate, only captures the prepayment incentive at the present time. It is by default (close to) zero for newly issued MBS. We highlight that variations in the mortgage rate capture variations in the expected future moneyness or prepayment incentive because the expected future mortgage rate is relatively slow-moving.

regressions over 1995–2021 show that a one-standard-deviation increase in the mortgage rate reduces the MBS convenience premium by about 18 bps and the monthly issuance amount by about $12 billion. We also find that the Treasury supply (measured by the U.S. debt-to-GDP ratio as in Krishnamurthy and Vissing-Jorgensen, 2012) negatively affects the MBS convenience premium and "crowds out" MBS issuance, which is consistent with substitutability between MBS and Treasuries in satisfying demand for safe assets.

The *negative* dependence of MBS premium on the mortgage rate is quite informative when one compares the prepayment-driven demand for MBS with the "opportunity cost of money" channel (Sunderam, 2014; Nagel, 2016). We first show that, like the long-term mortgage rate, the short-term federal funds rate also *negatively* affects the MBS convenience premium. This result runs opposite to the *positive* effect of the opportunity cost of money shown in the aforementioned literature—higher short-term interest rates imply higher opportunity costs of holding money, giving rise to higher convenience premia. This does not mean that the "opportunity cost of money" theory fails for MBS; in fact, when looking at *short-term* repos backed by long-term agency MBS, we recover a *positive* dependence of the MBS repo convenience premium on the federal funds rate. These findings not only differentiate our effects of prepayment-driven demand for MBS from those driven by the opportunity cost of money but also uncover a novel effect of repo contracts in transforming long-term bonds into short-term assets.

The baseline time-series regressions used so far may miss some "unobservable" aggregate factors that drive MBS convenience premia, confounding our estimates. We address this identification issue by exploiting the panel structure for newly issued MBS. In short, the existence of multiple newly issued MBS coupon stacks allows us to control for time-series fixed effects,[8] and the cross-sectional identification embedded in the panel regression hence helps "rule in" the channel of prepayment-driven demand. We find that the panel estimates are still negative and significant, confirming the baseline findings on the prepayment-driven MBS demand; yet, they are smaller in magnitude than the baseline time-series estimates, suggesting the existence of unobservable "demand" shocks (other than prepayment-driven factors). We also argue that the time-series estimates using the federal funds rate are likely robust to the aforementioned unobservable demand shocks.

Our second set of main analyses focuses on the safe-asset demand for agency MBS that arises from principal safety and regulatory constraints. In Section 3.3, we explore two policy

[8]These newly issued coupon stacks do not differ in secondary market liquidity. For example, their average trading costs fall within the tight range of 1.2–1.4 cents per $100 in par value; see Section 3.2.3 for details.

events as quasi-natural experiments to demonstrate these effects. The first is the placing of Fannie Mae (and Freddie Mac) into conservatorship on September 6, 2008, that was officially backed by the U.S. Treasury department. Before the conservatorship, they were private entities with only implicit U.S. government support.[9] The conservatorship would naturally induce an increase in demand for Fannie Mae MBS relative to those of Ginnie Mae, which has long been a wholly owned government agency. The second policy event is the introduction of the LCR rule in 2013, which assigned to Fannie Mae and Ginnie Mae MBS a haircut of 15 percent and zero percent, respectively, in computing HQLA holdings. This would induce a drop in banks' demand for Fannie Mae MBS relative to their demand for Ginnie Mae MBS.

We conduct standard different-in-differences analyses of MBS convenience premia using the short windows around the policy shocks (we do not examine issuance amounts because supply shifts are challenging to detect in short windows). Consistent with an increase in demand for Fannie Mae MBS relative to that for Ginnie Mae MBS, we find that the yield spread for Fannie Mae MBS mostly remained lower than that of Ginnie Mae before the conservatorship, but jumped above Ginnie Mae's afterwards. Difference-in-differences regressions using the one-year event window sample quantify the effects of conservatorship at about 49 bps. To address the possibility of confounding effects of default risk premia, we adjust the MBS yields by CDS spreads on Fannie Mae. This adjustment reduces the estimated conservatorship effect to 35 bps, which is still statistically significant and economically large. Similar analyses show that the effect of the LCR is about 15 bps. Interestingly, the LCR effect shows no change when we adjust for Fannie Mae CDS, which is consistent with the LCR event's working as a regulatory constraint shock rather than a shock to principal safety.

Finally, in Section 3.4, we examine a "structural" implication of the MIU framework used. Specifically, in the model, the ratio of the MBS convenience premium to the Treasury convenience premium recovers the demand for MBS relative to the demand for other safe assets *precisely* and is free of other driving forces (like demand of all safe assets or its equilibrium quantity). Hence, compared to the AAA-MBS yield spread, this ratio should provide greater explanatory power in our main regressions. Indeed, we find that the regression R^2 of the mortgage rate is 35% for the ratio, substantially higher than that of the AAA-MBS yield (only 2%). This not only delivers empirical support for the widely used "structural" frame-

[9]Related to this implicit government backing, see Nothaft, Pearce, and Stevanovic (2002) and references therein for studies of the yield spread between Fannie Mae/Freddie Mac debt and non-GSE debt. This yield spread captures the lower (corporate) funding cost of GSEs, differing from the agency MBS convenience premium that captures the lower funding cost of mortgage borrowers.

work of the safe asset convenience premium but also provides a measure that quantitatively captures the convenience benefit of agency MBS (relative to that of Treasury securities).

Unsurprisingly, the empirical measures we use are not perfect. In particular, because the adjustment for the value of prepayment options is based on statistical prepayment models, the MBS yield measure we use contains a (non-interest-rate) prepayment risk premium component. As shown by Boyarchenko et al. (2019), however, this component contributes very little to the time-series variations on which we focus. In fact, we find that the MBS-to-Treasury ratio in convenience premium—the "structural" measure of MBS-specific demand—cannot be explained by the prepayment risk premium measure of Boyarchenko et al. (2019); if anything, it runs in the opposite direction.[10]

Relatedly, using the current mortgage rate without subtracting the expected future mortgage rate to capture expected future moneyness likely brings about measurement errors. We stress that the aforementioned panel analysis using multiple newly issued MBS coupon stacks fully controls for such errors. For further robustness, in Section 3.5 we construct a measure of expected future moneyness—using the difference between the current mortgage rate and the forecast of future mortgage rates from Blue Chip Financial Forecasts—and find that the baseline effects remain significant. Finally, we show in Section 3.6 that the baseline results remain robust using monthly changes, addressing the potential concern of spurious correlations given the fairly persistent level series used in the baseline.

Our paper contributes to both the literature on the convenience premia of safe assets,[11] and the literature on agency MBS pricing.[12] To the best of our knowledge, the safe-asset literature has not examined the economic role of agency MBS as safe assets. In the MBS-pricing literature, several recent studies investigate cross-sectional variation in the prepayment risk premium (e.g., Gabaix et al., 2007; Boyarchenko et al., 2019; Diep et al., 2021). We complement these studies by examining the time-series dimension and the convenience premium for agency MBS associated with their safe-asset status. Moreover, our analysis of MBS repos complements Bartolini, Hilton, Sundaresan, and Tonetti (2011) and Song and Zhu (2019),

[10]We do not claim victory in separating the convenience premium entirely from the risk premium, which is a challenging task for the safe-asset literature. Instead, we view our analyses as a starting point from which to bring the safe-asset perspective into agency MBS pricing.

[11]Relatively recent studies include Du, Im, and Schreger (2018), Jiang, Krishnamurthy, and Lustig (2019), Fleckenstein and Longstaff (2020), He and Krishnamurthy (2020), Infante (2020), and He, Nagel, and Song (2022) among others. Gorton (2017) and Caballero et al. (2017) provide broad surveys.

[12]Relatively recent studies include Carlin, Longstaff, and Matoba (2014), Chernov, Dunn, and Longstaff (2018), Chen, Liu, Sarkar, and Song (2020), Diep, Eisfeldt, and Richardson (2021), and Fusari, Li, Liu, and Song (2021) among others. Relatedly, Duarte (2007), Hansen (2014), and Malkhozov, Mueller, Vedolin, and Venter (2016) study how mortgage-risk hedging affects Treasury bond returns.

who study agency MBS financing markets.[13]

2 Economic Framework

In this section, we present a simple economic framework and flesh out key implications when investors treat agency MBS as a class of safe assets.

2.1 Model

Safe asset demand. We follow the standard approach in the literature to model the demand for safe assets through a money-in-the-utility approach (Krishnamurthy and Vissing-Jorgensen, 2012; Nagel, 2016). In particular, a representative agent, endowed with a stream of perishable consumption good $\{A_t\}$, seeks to maximize

$$E_0 \left\{ \sum_{t=1}^{\infty} \beta^t \left[u \left(C_t \right) \right] \right\},$$

where

$$C_t \equiv c_t + \gamma_t v \left(Q_t \right) \tag{1}$$

with c_t denoting the agent's consumption on date t, and

$$Q_t \equiv B_t + \lambda_t M_t \tag{2}$$

gives the total amount of real liquidity holdings with M_t and B_t being the *real* balances of MBS and Treasury securities, respectively. The "convenience" benefit that the agent derives from the asset balance Q_t—which we include in the spirit of money balances—is modeled as a reduced-form function $v(Q_t)$, with $v'(\cdot) > 0$ and $v''(\cdot) < 0$. Insofar as we focus on the spread between nominal assets, our model is cast in real terms and hence abstracts away from inflation issues.[14]

The term γ_t in Eq. (1) captures time-varying demand for *all* safe assets. For example, γ_t would rise when investors engage in flight-to-safety behavior in economic downturns.

[13] In studying agency MBS as liquid and safe assets, our analysis is also related to the literature on MBS market liquidity and trading, including Downing, Jaffee, and Wallace (2009), Vickery and Wright (2011), Bessembinder, Maxwell, and Venkataraman (2013), Gao, Schultz, and Song (2017), Li and Song (2019), and Schultz and Song (2019), among others; Fuster, Lucca, and Vickery (2021) provide a broad survey.

[14] See Li, Fu, and Xie (2022) for an analysis of inflation expectations and the Treasury safe-asset premium.

In contrast, λ_t in Eq. (2) captures time-varying demand for MBS *relative to demand for other safe assets*—Treasury securities specifically in the model. This factor is driven by economic features that distinguish MBS from Treasury securities—including prepayment, implicit government backing, and regulatory treatment, as we explain in detail later.

The representative agent maximizes her utility subject to the following budget constraint:

$$B_{t-1}P_t^B + M_{t-1}P_t^M + A_t = c_t + B_tP_t^B + M_tP_t^M, \tag{3}$$

where P_t^B and P_t^M are the respective (real) prices of Treasuries and MBS in units of consumption and A_t is the endowment in period t.[15] The first-order condition for c_t is

$$1 + \beta E_t \left[\frac{u'(C_{t+1})}{u'(C_t)} \left(-\frac{P_{t+1}^B}{P_t^B} \right) \right] = 0, \tag{4}$$

while the first-order condition for M_t is

$$\gamma_t v'(Q_t)\lambda_t + \beta E_t \left[\frac{u'(C_{t+1})}{u'(C_t)} \left(-P_t^M \frac{P_{t+1}^B}{P_t^B} + P_{t+1}^M \right) \right] = 0. \tag{5}$$

Combining equations (4) and (5), we have

$$P_t^M = \underbrace{\lambda_t \gamma_t v'(Q_t)}_{\text{MBS convenience}} + \beta E_t \left[\frac{u'(C_{t+1})}{u'(C_t)} P_{t+1}^M \right]. \tag{6}$$

Similarly, for Treasuries, we have

$$P_t^B = \underbrace{\gamma_t v'(Q_t)}_{\text{Treasury convenience}} + \beta E_t \left[\frac{u'(C_{t+1})}{u'(C_t)} P_{t+1}^B \right]. \tag{7}$$

Both are standard Euler equations for bonds but with the adjustment of "convenience" terms specifically for MBS and Treasury securities.

To derive convenience premia, we consider, for simplicity, one-period Treasuries and MBS

[15] This setup assumes that it is the agent's liquidity holdings at the end of the period, after having purchased consumption goods, that yield utility. Alternative timing assumptions, e.g., that liquidity holdings that are available *before* the purchase of consumption goods yield utility, do not change the main implications. See Carlstrom and Fuerst (2001) for such an alternative timing assumption and Walsh (2017) for general discussions.

with $P^M_{t+1} = 1$ and $P^B_{t+1} = 1$. Define the MBS yield as $r^M_t \equiv -\ln\left(P^M_t\right)$. We then have

$$\begin{aligned} r^M_t \approx 1 - P^M_t &= 1 - E_t\left[\frac{\beta u'\left(C_{t+1}\right)}{u'\left(C_t\right)}\right] - \lambda_t \gamma_t v'\left(Q_t\right) \\ &\approx r_t - \lambda_t \gamma_t v'\left(Q_t\right), \end{aligned}$$

where equation (6) is used in the second equality, and $r_t \approx 1 - E_t\left[\frac{\beta u'(C_{t+1})}{u'(C_t)}\right]$ is the real rate applicable to assets that do not produce a safety service flow. We therefore define the convenience premium for MBS as

$$s^M_t \equiv r_t - r^M_t = \lambda_t \gamma_t v'\left(Q_t\right). \tag{8}$$

Similarly, the convenience premium for Treasury securities is defined as

$$s^B_t \equiv r_t - r^B_t = \gamma_t v'\left(Q_t\right). \tag{9}$$

Safe asset supply. We assume that Treasury supply B_t is exogenously determined by the government, as in Krishnamurthy and Vissing-Jorgensen (2012). The MBS supply M_t is, instead, endogenously determined by banks, which intermediate between mortgage borrowers and representative agents (who are savers). Specifically, a continuum of banks of mass one securitize mortgage loans from mortgage borrowers as MBS, which they then sell to our representative agents. For simplicity, we assume that banks have monopoly market power (see Scharfstein and Sunderam (2017) for empirical evidence of banks' market power in the mortgage market) and mortgage borrowers are rate inelastic.[16]

Per dollar of MBS, mortgage borrowers are willing to pay a rate of up to r_t (maximum willingness-to-pay), while, by Eq. (8), savers only require a rate of r^M_t. Therefore, given a quantity of M_t dollars in MBS, the total gain is $M_t(r_t - r^M_t) = M_t s^M_t$, which goes to the (monopolistic) banking sector. We further assume that banks incur a private cost $\kappa(M_t)$ with $\kappa'(\cdot) > 0$ and $\kappa''(\cdot) > 0$ as in Sunderam (2014). Banks solve $\max_{M_t}\left\{s^M_t M_t - \kappa\left(M_t\right)\right\}$ with the standard first-order condition $\kappa'\left(M_t\right) = s^M_t$. Because $\kappa''(\cdot) > 0$, M_t is a monotonically increasing function of s^M_t, holding all else equal.

[16]In consequence, the primary mortgage rate paid by borrowers in the model equals the risk-free rate r_t. In practice, some portion of demand for housing is indeed rigid, including demand related to setting up a family, moving to a good school district, and relocation. Importantly, an alternative setup with competitive banks and elastic household demand for mortgages would deliver the same results. In this case, the convenience premium can be passed on to mortgage borrowers and reflected in the mortgage rate; the related empirical issue will be addressed in Section 3.2.3.

Equilibrium. Define $\phi(\cdot) \equiv [\kappa'(\cdot)]^{-1}$. The discussion in the previous paragraph implies that

$$M_t = \phi\left(s_t^M\right). \tag{10}$$

Plugging this into (8) and (9), we have

$$s_t^M = \lambda_t \gamma_t v'(Q_t), \tag{11}$$
$$s_t^B = \gamma_t v'(Q_t), \tag{12}$$

where $Q_t = B_t + \lambda_t \phi\left(s_t^M\right)$. The equilibrium quantity M_t, as well as equilibrium convenience premia s_t^M and s_t^B, are given by equations (10), (11), and (12).

2.2 Model Implications for Empirical Testing

Our simple model offers the following empirical predictions.

Demand λ_t for MBS. We focus on the distinctive economic channel—demand for MBS *relative to* demand for Treasury securities λ_t. Intuitively, an increase in λ_t shifts the demand curve of MBS upward so that both the convenience premium s_t^M and supply M_t increase.

Proposition 1. ***[Effects of λ_t on MBS convenience premium and issuance]*** *The MBS convenience premium and supply increase with demand for MBS relative to demand for other safe assets: $ds_t^M/d\lambda_t > 0$ and $dM_t/d\lambda_t > 0$.*

We consider three economic drivers that affect the safe-asset demand for MBS λ_t—prepayment, principal safety, and regulatory constraint. First, prepayment is a unique feature of MBS for which the timing of cash flows to investors is uncertain because mortgage borrowers can prepay without penalty. This feature hurts MBS investors as borrowers often prepay when interest rates decline (Gabaix et al., 2007). Naturally, prepayment concerns would negatively affect investor demand for MBS relative to demand for other safe assets like Treasury securities that are not subject to uncertain cash-flow timing; such an effect could be microfounded based on either prepayment modeling complexity along the line of Hansen and Sargent (2001), and/or information asymmetry as in Gorton and Pennacchi (1990).

Second, the safety of principal balances is another distinctive feature of agency MBS. In particular, the principal balance of an MBS is guaranteed by Fannie Mae, Freddie Mac, and Ginnie Mae when mortgage borrowers default. Usually known as Government-Sponsored Enterprises (GSEs), Fannie Mae and Freddie Mac were private entities with implicit U.S.

government support before September 2008 but have been in conservatorship with explicit government support since then. Over the last decade, many initiatives have been proposed for privatizing GSEs. Therefore, the safety of principal balances of agency MBS is similar to that of Treasury securities in general, but the strength of government backing is weaker and subject to uncertainty, which could affect investor demand for MBS.

Third, agency MBS have played a prominent role in monetary and regulatory policies since the 2007–2009 global financial crisis. In particular, as discussed in introduction, agency MBS are included as important HQLAs in the LCR requirement of Basel III for bank regulations, receiving a haircut similar to that assigned to Treasury securities but more favorable than that assigned to other AAA-rated assets. Such regulatory constraint should affect investor demand for agency MBS as safe assets.

Demand for all safe assets λ_t and the Treasury supply B_t. We now consider the effects of demand for *all* safe assets γ_t and the Treasury supply B_t. Although these effects have been examined in existing studies and hence are not our focus, spelling them out is helpful for comparison purposes.

Proposition 2. ***[Effects of γ_t and B_t on MBS convenience premia and issuance]***

(a). MBS convenience premia and issuance decrease with the Treasury supply: $ds_t^M/dB_t < 0$ and $dM_t/dB_t < 0$; and

(b). MBS convenience premia and issuance increase with demand for all safe assets: $ds_t^M/d\gamma_t > 0$ and $dM_t/d\gamma_t > 0$.

Intuitively, an increase in B_t reduces the MBS convenience premium because the marginal benefit of liquidity holdings decreases ($v''(\cdot) < 0$); a lower convenience premium then induces a drop in MBS issuance, resulting in a crowding-out effect. In contrast, an increase in γ_t shifts the demand curve for all safe assets upward, raising both MBS convenience premium and its issuance. Potential drivers of γ_t include flight-to-safety behavior and the "opportunity cost of money" theory of the liquidity premium; see Sunderam (2014) and Nagel (2016) for empirical evidence of these drivers for short-term Treasury securities.

Ratio of MBS convenience premium to the Treasury convenience premium. As shown so far, the convenience premium s_t^M in Eq. (11) depends not only on the MBS-specific demand factor λ_t, but also on the demand factor γ_t for all safe assets and the equilibrium quantity Q_t of all safe assets. A "structural" implication of our standard safe-asset modeling, as can be seen in (11) and (12), is that the ratio s_t^M/s_t^B eliminates both γ_t and Q_t and precisely recovers λ_t, the MBS-specific demand factor emphasized by our paper.

Proposition 3. ***[Ratio of the MBS convenience premium to the Treasury convenience premium]*** *The ratio of MBS convenience premium to Treasury convenience premium s_t^M/s_t^B is equal to λ_t.*

As a result, with confounding effects excluded, the ratio of MBS convenience premium to Treasury convenience premium should be a better proxy for MBS-specific demand for safe assets, relative to MBS convenience premium per se. We test this empirical implication in Section 3.4.

3 Empirical Analyses

In this section, we first explain our main empirical measures, and then present the empirical findings for MBS-specific-demand drivers associated with prepayment, the safety status of issuing agencies, and regulatory constraints. We also provide empirical support for the "structural" implication that the ratio of the MBS convenience premium to the Treasury convenience premium recovers the MBS-specific demand.

3.1 Empirical Measures

We introduce the empirical measures used in our analyses briefly here; Appendix C provides details regarding the data and constructions of our empirical measures.

Measures of convenience premia. Following Krishnamurthy and Vissing-Jorgensen (2012), we use AAA corporate bonds as the benchmark and measure the MBS convenience premium by the AAA-MBS yield spread. For AAA corporate bonds, we use the Bloomberg Barclays corporate bond total-return index series. For MBS, we use yields of Fannie Mae 30-year "production-coupon" MBS (FN30y), also from Bloomberg Barclays total-return index series. These are the MBS that have the largest issuance amounts among various coupon stacks, carry an average loan rate that is closest to the prevailing mortgage rate, and are traded most actively (Gao et al., 2017). MBS yields are adjusted for the value of prepayment options based on a prepayment model (Gabaix et al., 2007; Boyarchenko et al., 2019; Song and Zhu, 2019). We further adjust the AAA-MBS yield spread for potential duration mismatch between corporate bonds and MBS using measures of durations and the

Table 1: Summary Statistics of Yield Spreads and Issuance

	mean	sd	min	p25	p50	p75	max
A: MBS Yield Spreads and Issuance Amount							
$s^{AAA-FN30y}$	46.91	46.18	2.13	25.35	37.45	53.24	372.63
$s^{AAA-Tsy}$	84.10	51.15	46.63	60.75	69.71	89.10	429.13
MBS Issuance	18.37	12.87	1.51	10.88	15.77	21.40	76.97
B: Short-Term Repo Spreads							
CD−MBS	3.05	16.98	−27.75	−3.79	0.81	4.74	152.33
CD−Treasury	14.06	29.91	−24.65	2.73	7.05	13.09	295.66

Panel A reports the mean, standard deviation (sd), minimum (min), 25th percentile (p25), median (p50), 75th percentile (p75), and maximum of monthly series of the AAA-FN30y yield spread ($s^{AAA-FN30y}$), and AAA-Treasury yield spread ($s^{AAA-Tsy}$), all in bps, as well as the monthly new issuance amount of FN30y MBS in $billions. Panel B reports the same summary statistics for monthly series of the spread between CD and MBS repo rates and the spread between CD and Treasury repo rates. The sample period is October 1995–December 2021 in Panel A and January 2004–December 2021 in Panel B.

Treasury yield curve. The resulting duration mismatch–adjusted yield spread is denoted by $s^{AAA-FN30y}$. For comparison, we also obtain the maturity-matched AAA-Treasury yield spread as a measure of the Treasury convenience premium, denoted $s^{AAA-Tsy}$.

In the first two rows of Table 1 we report summary statistics for monthly MBS and Treasury convenience premia (in bps) from October 1995 through December 2021. The mean MBS convenience premium is 47 bps, about half of the mean Treasury convenience premium (84 bps). The time series variability is similar, both with a standard deviation of about 50 bps. In the top left panel of Figure 2 we plot monthly series of AAA-FN30y and AAA-Treasury yield spreads.

Measures of the MBS supply. We use the monthly new issuance amount of FN30y MBS to measure the MBS supply M_t, which reacts in equilibrium to λ_t in our model. New issuance amount, as a "flow" measure, therefore matches M_t better than the outstanding MBS "stock" that includes seasoned MBS driven by past market conditions.

In the third row of Panel A in Table 1 we report summary statistics for the monthly issuance amount of FN30y MBS (in $billions). The mean monthly issuance is about $18 billion, with a standard deviation of $13 billion. In the top right panel of Figure 2 we plot monthly series of FN30y issuance amounts. This series experienced an upward trend until

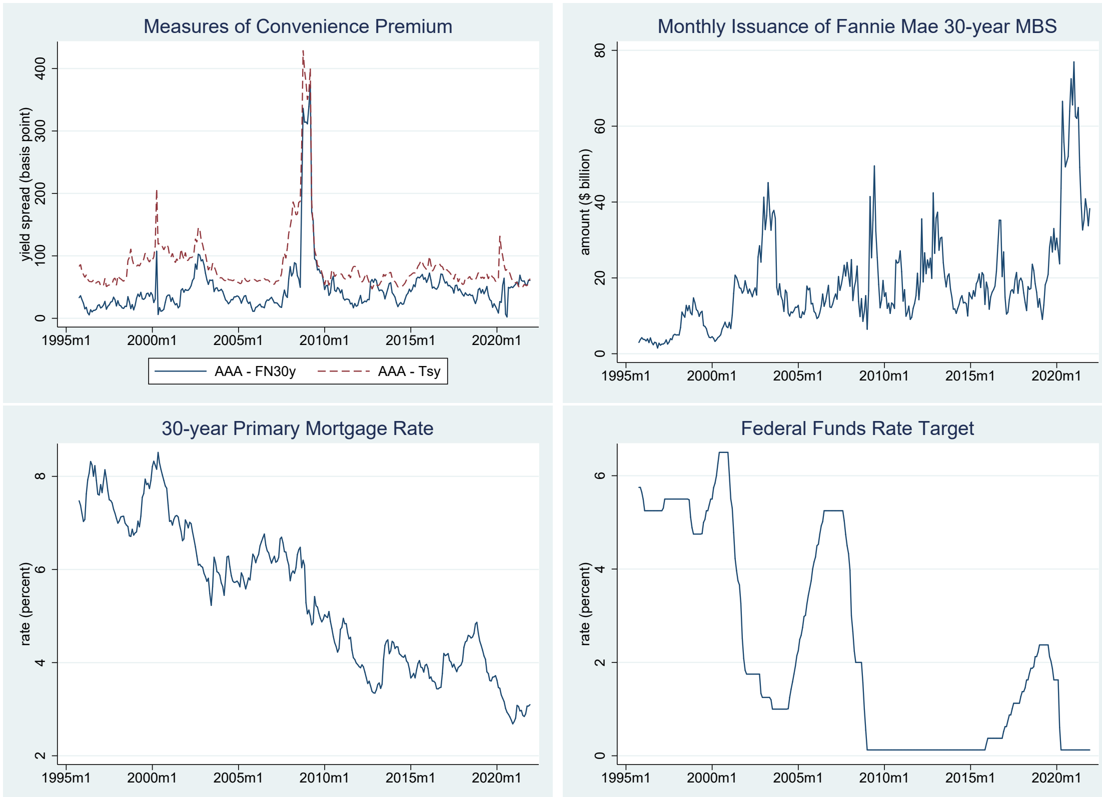

Figure 2: Monthly Series of Empirical Measures

This figure plots monthly series of the AAA-FN30y yield spread (top left panel), the monthly issuance amount of FN30y MBS (top right panel), the 30-year mortgage rate (bottom left panel), and the federal funds target rate (bottom right panel). The sample period is from October 1995 through December 2021.

2001, with an average monthly issuance of $10 billion and remained stable afterwards at an average monthly issuance of around$30 billion. The issuance shot up substantially when the federal funds rate reached record-low levels in 2002–2003, 2008–2009, and especially after the COVID shock in 2020.

Measures of the prepayment incentive. The prepayment incentive of an MBS is usually measured by the difference between the rate on its underlying mortgage loans and the current mortgage rate, known as "moneyness." However, this standard moneyness measure only captures the prepayment incentive at the present time but not the *expected* prepayment incentive in the future, which is particularly relevant for the pricing of production-coupon MBS (for which the standard moneyness measure is by default equal to zero). We measure the expected future prepayment incentive of production-coupon MBS using the level of mortgage rate directly; a higher mortgage rate today indicates a greater expected moneyness in the future when the interest rate reverts to its long-run mean. That is, variations in the mortgage rate capture variations in the expected future moneyness because the expected future mortgage rate is relatively slow-moving.

For the FN30y MBS we consider, we use the rate for 30-year fixed-rate mortgage loans from the Primary Mortgage Market Survey (PMMS) conducted by Freddie Mac. Because short-term and long-term interest rates are closely tied with each other, we also obtain the federal funds target rate as another measure of interest rates. In the bottom panels of Figure 2 we plot monthly series of PMMS and the federal funds rate, both of which exhibit a downward trend between the 1990s and 2015.

Convenience premium measures of short-term safe assets. Agency MBS and Treasury bonds are long-term safe assets. To facilitate a more appropriate comparison with research on short-term safe assets (e.g., Nagel, 2016), we consider MBS repos and Treasury repos that are short-term safe assets. We measure their convenience premia using the spread of one-month general collateral (GC) repo rates of MBS and Treasuries relative to one-month certificate of deposit (CD) rates. We obtain repo rates, which are available starting in 2004, from Bloomberg, and obtain CD rates from Federal Reserve Economic Data (FRED). Panel B of Table 1 reports summary statistics for the CD–MBS repo spread and the CD–Treasury repo spread from January 2004 through December 2021. The mean CD–MBS repo spread is about 3 bps, below the CD-Treasury repo spread of about 14 bps.

Treasury supply and other variables. We measure the Treasury supply (B_t in the model) based on the quarterly series of the outstanding U.S. government debt-to-GDP ratio from Federal Reserve Economic Data (FRED) reported by the Federal Reserve Bank of St. Louis. We linearly interpolate the monthly series and use the logarithm of the debt-to-GDP ratio in the empirical analysis, as in Krishnamurthy and Vissing-Jorgensen (2012) and Nagel (2016).[17] As control variables, we also obtain the VIX series from the CBOE and compute the slope of the yield curve as the difference between 10-year and 3-month Treasury yields, based on Gurkaynak, Sack, and Wright (2007).

[17] In our model the Treasury supply is taken as exogenous. The outstanding balance of Treasury securities, as a "stock" measure, matches B_t in the model and captures the effect of a change in investors' total Treasury holdings on equilibrium demand for MBS.

3.2 Prepayment-Driven Demand for MBS

In this section, we present our analyses of the prepayment-driven demand for MBS λ_t.

3.2.1 Baseline analysis

As set out in Proposition 1, prepayment-driven demand for MBS depends *negatively* on the prepayment incentive. For the production-coupon MBS we focus on, we measure the future prepayment incentive using the mortgage rate PMMS, as discussed in Section 3.1. Hence, the hypothesis to test is that the MBS convenience premium and issuance amount depend negatively on PMMS. In columns (1) and (2) of Table 2 we report monthly time-series regressions of $s^{AAA-FN30y}$ and issuance amount of FN30y MBS on PMMS, respectively. We compute robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ (such standard errors are used in all regressions unless specified otherwise). Indeed, PMMS negatively affects both $s^{AAA-FN30y}$ and the issuance amount, with high statistical significance.

We then add other variables to the regressions and report the results in columns (3) and (4). In particular, we include Log(Debt/GDP) as a measure of the Treasury supply and find that it negatively affects the MBS convenience premium and issuance amount, consistent with Proposition 2 (a). This crowding-out effect confirms the substitutability of agency MBS for Treasury securities in satisfying demand for safe assets.[18] We also include the VIX and the slope of the yield curve as controls. As discussed in Krishnamurthy and Vissing-Jorgensen (2012), stock-return volatility is the key input into the expected default frequency measure from Moody's Analytics and controls for corporate default risk, while the slope of the yield curve captures the state of business cycles and controls for the risk premium. Moreover, VIX can also control for flight-to-safety behavior (Nagel, 2016). We observe that VIX is significant in affecting both $s^{AAA-FN30y}$ and issuance amount (the negative signs are consistent with a flight-to-safety effect; see Proposition 2 (b)), though the slope is significant only for the former. Importantly, even with these three variables included as regressors, the regression coefficients on PMMS remain negative and statistically significant.

Using PMMS itself (without subtracting the expected future mortgage rate) to capture expected future moneyness likely brings about measurement errors. We conduct two analyses to address this issue. First, we conduct a panel analysis using multiple newly issued MBS coupon stacks for which we can fully control for the missing of expected future mortgage rate

[18] Sunderam (2014) and Greenwood et al. (2015), among others, also document crowding-out effects of the Treasury supply on asset-backed commercial paper and unsecured financial commercial paper.

Table 2: Effects of Mortgage Rate on MBS Convenience Premium and Issuance

	(1) $s^{AAA-FN30y}$	(2) MBS Issuance	(3) $s^{AAA-FN30y}$	(4) MBS Issuance
PMMS	−4.117***	−5.164***	−11.337***	−7.629***
	(−2.816)	(−5.920)	(−4.095)	(−8.539)
Log(Debt/GDP)			−26.016**	−10.413**
			(−2.393)	(−2.385)
VIX			3.254**	0.358**
			(2.466)	(2.235)
Slope			7.874***	−1.190
			(3.027)	(−1.423)
Intercept	69.106***	46.215***	130.955**	95.476***
	(7.489)	(8.312)	(2.565)	(4.765)
N	315	315	315	315
R^2	0.019	0.390	0.453	0.456

Columns (1)–(2) report monthly time series regressions of $s^{AAA-FN30y}$ and MBS issuance amount on PMMS, respectively. Columns (3)–(4) add Log(Debt/GDP), VIX, and slope of the yield curve as regressors. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. The sample period is October 1995–December 2021. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

using time fixed effects (Section 3.2.3). Second, we use the difference between PMMS and the forecast of the future mortgage rate from Blue Chip Financial Forecasts as a measure of expected future moneyness (Section 3.5). Both analyses confirm our main findings.

3.2.2 The opportunity cost of money and federal funds rate

The long-term mortgage rate is strongly correlated with the short-term interest rate; as shown in column (1) of Table 3, regressing PMMS on the federal funds rate delivers a significantly positive coefficient and a high R^2 of 73%. As discussed in Section 2.2, short-term interest rates can affect convenience premia for safe assets through the "opportunity cost of money" channel. We therefore conduct two sets of analyses to compare the effects of the prepayment-driven demand for MBS with the effects of the opportunity cost of money.

In the first analysis, we regress $s^{AAA-FN30y}$ and the issuance amount on the federal funds rate and report the results in columns (2)–(5) of Table 3. We observe that, as is the case

Table 3: Effects of the Federal Funds Rate on MBS Convenience Premium

	(1) PMMS	(2) $s^{AAA-FN30y}$	(3) MBS Issuance	(4) $s^{AAA-FN30y}$	(5) MBS Issuance
FFR	0.607***	−6.532***	−3.155***	−8.710***	−6.154***
	(17.331)	(−3.587)	(−5.889)	(−3.027)	(−8.281)
Log(Debt/GDP)				−20.871*	−8.150*
				(−1.873)	(−1.709)
VIX				3.193**	0.319**
				(2.413)	(2.080)
Slope				−0.037	−6.865***
				(−0.009)	(−5.746)
Intercept	4.032***	61.535***	25.437***	84.292*	70.049***
	(28.100)	(6.957)	(11.057)	(1.692)	(3.398)
N	315	315	315	315	315
R^2	0.730	0.096	0.288	0.448	0.444

Columns (1)–(2) report monthly time series regressions of $s^{AAA-FN30y}$ and issuance amount on 30-year mortgage rate (PMMS), respectively. Columns (3)–(4) add Log(Debt/GDP), VIX, and slope of term structure as regressors. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. The sample period is October 1995–December 2021. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

with the mortgage rate, the federal funds rate affects $s^{AAA-FN30y}$ and the issuance amount in a significantly *negative* way. That is, the higher the short-term interest rate, the lower the MBS convenience premium. This negative comovement stands in sharp contrast to the *positive* comovement implied by the theory of the opportunity cost of money; according to this theory, higher short-term interest rates should imply higher opportunity costs for holding money and hence higher convenience premia for safe assets (see Proposition 2).

Empirical support for the theory of the opportunity cost of money has been be found in the literature on short-term safe assets (Nagel, 2016). Hence, in the second analysis, we analyze how convenience premia of short-term safe assets depend on short-term interest rates. As no short-term agency MBS such as T-bills are available, we focus on MBS repos, which effectively "transform" long-term MBS into short-term safe assets. We also consider Treasury repos for comparison purposes. In the first two columns of Table 4, we report results obtained by regressing CD-Treasury repo spreads on the federal funds rate and find that, consistent with Nagel (2016), the regression coefficients are significantly positive. More

Table 4: Repo Spreads and the Level of Interest Rates

	(1) CD-Treasury	(2) CD-Treasury	(3) CD-MBS	(4) CD-MBS
Federal Funds Rate	4.444**	18.234***	1.454**	10.684***
	(2.380)	(2.591)	(1.982)	(2.604)
Log(Debt/GDP)		32.661		29.026**
		(1.490)		(2.227)
VIX		1.796***		0.762**
		(3.047)		(2.383)
Slope		15.361**		9.059**
		(2.235)		(2.176)
Intercept	8.270***	−204.842*	1.161	−160.285**
	(2.871)	(−1.771)	(0.670)	(−2.363)
N	215	215	215	215
R^2	0.058	0.427	0.019	0.233

Columns (1)–(2) report results of monthly time series regressions of the spread between CD and Treasury repo rates on federal funds rate, while columns (3)–(4) report those for the spread between CD and MBS repo rates. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. The sample period is February 2004–December 2021. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

importantly, as shown in the last two columns, the regression coefficients of the CD-MBS repo spreads on the federal funds rate are also significantly *positive*, in stark contrast to the significantly negative dependence of $s^{AAA-MBS}$ on the federal funds rate (as reported above in Table 3).[19]

Overall, these results show that the MBS convenience premium depends *negatively* on short-term interest rates, which differentiates the effects of prepayment-driven demand for MBS from the effects of the opportunity cost of money.[20] This negative dependence contrasts strikingly with the *positive* dependence of the convenience premium of MBS repo, demonstrating a novel effect of repo contracts transforming long-term bonds into short-term assets. One likely reason for the irrelevance of prepayment risk to MBS repo is that the repo

[19] All the regression results remain similar when we use 1-month Eurodollar Deposit rates instead of CD rates as the benchmark.

[20] Moreover, Vissing-Jorgensen (2015) finds that the long-term–Treasury convenience premium does not depend significantly on the federal funds rate, casting doubt on the effect of the opportunity cost of money for long-term safe assets. Consistent with her finding, we do not find that the AAA-Treasury yield spread depends significantly on the federal funds rate (or the mortgage rate) in our data sample.

haircuts insulate cash lenders from the prepayment risk of the MBS collateral.

The novel finding on MBS repo bears further implications for the underlying drivers of investors' demand for short-term safe assets, which is a focus in many existing studies (Sunderam, 2014; Carlson et al., 2016; Nagel, 2016; Kacperczyk et al., 2021). In particular, Panel B Table 1 shows that the Treasury repo convenience premium is about 11 bps lower than that of MBS repo, implying that investors prefer Treasury collateral in the repo market. Without noticeable difference in their secondary market liquidity measures,[21] this may arise from Treasury securities' favorable regulatory treatment (say, in the calculation of risk-based capital or liquidity coverage ratio), strong government backing, or inexposure to prepayment risk. Our finding on the irrelevance of prepayment risk for MBS repo therefore suggests that investors' preference for Treasury collateral over MBS likely reflects the former two economic drivers.[22]

3.2.3 Panel data with cross-sectional identification

One concern regarding the baseline findings documented above is that some "unobservable" drivers of MBS convenience premia might be missing from the time-series regressions used so far, potentially confounding our estimates. Such drivers include unobservable demand shocks to MBS or all safe assets, as well as unobservable MBS supply shocks; for instance, time-varying appetite on the part of foreign investors may drive the MBS convenience premium and also affect mortgage rates in equilibrium.

We address this identification issue by exploiting the panel structure of newly issued MBS, for which we can include time-series fixed effects as controls. In particular, mortgage borrowers can receive widely varying mortgage rates because of differences in loan characteristics (such as loan amount, occupancy, and loan-to-value ratio), borrower characteristics (such as credit score, debt-to-income ratio, and employment status), and lender characteristics (such as the size, the pricing model, and whether the lender is a commercial bank or mortgage financing company). These loans with distinct mortgage rates are usually packaged into MBS with a range of coupon rates, which are mostly in 50-basis-point increments

[21] The liquidity difference between newly issued MBS and Treasury securities is negligible. For example, in Table A.1 we report that the average trading cost of newly issued agency MBS is about 1.2–1.4 cents per $100 in par value, similar to the trading cost of Treasury securities reported in Fleming, Mizrach, and Nguyen (2018) (e.g., the bid–ask spread is about 1.8 cents per $100 in par value for on-the-run 10-year Treasuries).

[22] That is to say, repo investors prefer Treasury over MBS for either favorable regulatory treatments, or for the stronger government backing of Treasuries during rare disaster events (modeled as jump risk).

(e.g., 4.5%, 4.0%, 3.5%, etc) and are often known as coupon stacks.[23] At any point in time, there are usually two or three coupon stacks in active issuance.

We obtain yields and issuance amounts for the three coupon stacks of Fannie Mae 30-year MBS with the most active issuance activities. In Panel A of Table 5 we report summary statistics for these MBS, where an issuance rank of 1 (3) indicates the coupon stack that has the largest (smallest) issuance amount in each month; coupon stack 1 is the production-coupon MBS.[24] Not surprisingly, the current moneyness (equal to MBS coupon rate minus current coupon rate) of coupon stack 1 is closest to zero (0.21%) on average. Compared with the issuance amount of coupon stack 1, the issuance amounts of the other two are lower but still fairly sizeable, about \$9.2 and \$3.265 billion, respectively. Moreover, the average convenience premium is lower for lower-issuance coupon stacks.

We then run panel regressions of $s^{AAA-FN30y}$ and issuance amount on the coupon rate using the sample comprising these MBS coupon stacks. Time fixed effects are included, so these are equivalent to regressions on the difference between the current mortgage rate of the MBS and the expected future mortgage rate. In the first two columns of Panel B in Table 5, we report results using all three coupon stacks, while in the last two columns we report results using only the top two coupon stacks. We observe that the coefficients on the coupon rate are significantly negative in all specifications, consistent with the baseline results.

One may be concerned about the liquidity difference across these coupon stacks. As shown in Table A.1, however, during the 2011–2015 period for which we have MBS transaction data, trading costs are similar across the three coupon stacks (about 1.2–1.4 cents per \$100 in par value).[25] Overall, the negative effects of the mortgage rate on the MBS convenience premium and issuance amount identified by cross-section data help "rule in" the prepayment-driven demand channel for MBS.[26]

[23]An MBS coupon, or pass-through coupon rate, represents the amount of interest cash flow an MBS investor receives every year on the outstanding unpaid principal balance of the underlying mortgage loans.

[24]The summary statistics for $s^{AAA-MBS}$ and issuance amount are not exactly equal to those reported in Table 1 because for the panel sample of Table 5, we drop all coupon cohorts of a month in which the observations for the non-production-coupon MBS are either missing or have data errors.

[25]If anything, coupon stack 1, which has the highest convenience premium, also involves the highest trading cost. Moreover, this stack has the lowest ratio of trading volume to issuance amount or turnover.

[26]It is worth comparing our cross-sectional analysis with those conducted in several recent papers, including Boyarchenko et al. (2019); Diep et al. (2021); Fusari et al. (2021). Besides examining the determinants of MBS issuance amount, our paper differs from these studies in that we consider newly issued MBS only, whereas these studies include both newly issued and seasoned MBS. By using newly issued MBS only, our analyses are less affected by the liquidity difference between newly issued and seasoned MBS (much like the difference between on-the-run and off-the-run Treasury securities studied in Krishnamurthy (2002)).

Table 5: Panel Analysis of the MBS Convenience Premium and Issuance

A: Sample Summary									
	Moneyness			Issuance			$s^{AAA-MBS}$		
Issuance Rank	mean	p25	p75	mean	p25	p75	mean	p25	p75
1	0.214	−0.123	0.531	17.701	10.847	21.021	47.94	26.53	57.52
2	0.356	−0.054	0.854	9.200	5.290	10.701	46.85	24.82	57.84
3	0.423	−0.158	1.029	3.265	1.789	4.390	43.84	22.94	52.30

B: Regressions				
	ALL		Issuance Rank≤2	
	$s^{AAA-MBS}$	MBS Issuance	$s^{AAA-MBS}$	MBS Issuance
Coupon rate	−6.112***	−4.859***	−4.028**	−7.599***
	(−5.979)	(−6.545)	(−2.263)	(−4.124)
Intercept	39.828***	3.349***	36.767***	2.669***
	(171.525)	(19.859)	(903.963)	(63.381)
N	920	920	618	618
R^2	0.977	0.500	0.986	0.696
Time FE	Yes	Yes	Yes	Yes

Panel A reports summary statistics (the mean, 25th percentile, and 75th percentile) of the moneyness (equal to MBS coupon rate minus current coupon rate), monthly issuance amount, and yield spread relative to AAA corporate bonds, for each of the three coupon stacks with the most active issuance activities. The coupon stack with issuance rank equal to 1 (3) refers to the coupon stack that has the largest (smallest) issuance amount in each month. Panel B reports panel regressions of AAA-MBS yield spread and issuance amount on the coupon rate, with time fixed effects. Robust t-statistics based on standard errors clustered at the coupon level are reported in parentheses. The sample period is October 1995–December 2021. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

3.2.4 Economic magnitude

Having shown that the negative effects of prepayment on MBS convenience premium are significant in various empirical specifications, we now look into the economic magnitude.

As a standard approach, we calculate the potential change in the MBS convenience premium and issuance amount corresponding to a one–standard-deviation change in the mortgage rate (1.55% as reported in Table 1). Based on the panel estimates reported in the first column of Panel B in Table 5, a one-standard-derivation increase in the mortgage rate reduces the MBS convenience premium by about 10 bps ($\approx -6.112 \times 1.55$) and the monthly issuance amount by about \$8 billion ($\approx -4.859 \times 1.55$); these are around 20% and 40% of their mean values, respectively (as reported in Table 1).

We then examine the magnitude differences between the baseline time-series estimates in Table 2 and the panel estimates in Table 5 to understand the potential effects of unobservable drivers (other than prepayment-driven factors). We observe that the time-series estimates (-11.337 and -7.629) are about twice of panel estimates (-6.112 and -4.859), suggesting that unobservable "demand" shocks result in upward bias (in magnitude) of time-series estimates. One leading candidate for explaining such shocks is the time-varying appetite on the part of foreign investors: a negative demand shock could *reduce* the MBS convenience premium, which, if passed on to mortgage borrowers, would *raise* the mortgage rate.

It is worth pointing out that the time-series estimates using the federal funds rate in Table 3 are likely robust to the aforementioned unobservable demand shocks. The reason is that the Fed is unlikely to adjust its target rate in response to such shocks, and even if the Fed did so, it would cut the federal funds rate downward to suppress rising mortgage rates, contravening the strong positive association of the mortgage rate and the federal funds rate in the data; see column (1) of Table 3. Hence, the significantly negative effects of the federal funds rate on the MBS convenience premium and issuance amount reported in Table 3 also provide support to the prepayment-driven demand channel highlighted by this paper.[27]

3.3 Safety and Regulatory Constraints: Policy Shocks

To examine the safety and regulatory-constraint channels of MBS demand, we use two policy events as quasi-natural experiments. The first is the placing of Fannie Mae (and Freddie Mac) into conservatorship as announced by the Federal Housing Finance Agency (FHFA) on September 6, 2008, and the second is the progressive implementation of the LCR rule that began in 2013. To control for confounding effects, we use a relatively short window around the policy events and hence focus on their effects on convenience premia (as the effects on MBS issuance likely take longer to materialize).[28]

Conservatorship. Prior to the commencement of the conservatorship on September 6, 2008, Fannie Mae was a private entity and believed to carry an implicit government guaran-

[27]Unobservable "supply" shocks can arise because household mortgages vary as a result of income shocks or mortgage cost changes (e.g., because of movements in interest expenses or refinancing fees), which lead to variations in MBS issuance. Such supply shocks imply that the MBS convenience premium and issuance amount should move in opposite directions as higher supplies reduce the marginal benefit of MBS holdings ($v''(\cdot) < 0$ in the model). But this is inconsistent with empirical results documented in Table 2.

[28]A related study by Gete and Reher (2021) shows that the liquidity coverage ratio contributes to the expansion of shadow banks in the mortgage origination market.

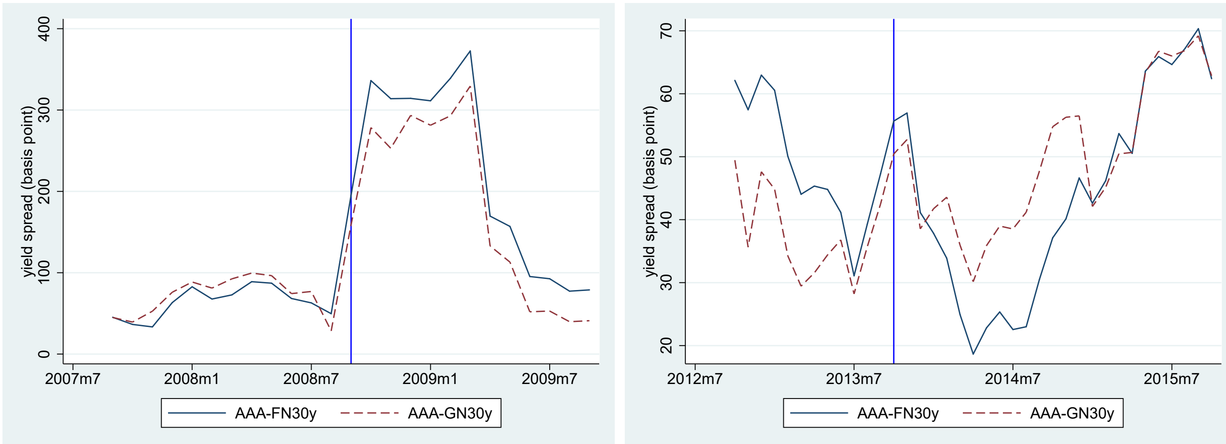

Figure 3: Policy Shocks and Convenience Premium Changes

This figure plots monthly series of the AAA-FN30y and AAA-GN30y yield spreads from September 2007 to September 2009 (in the left panel) and from October 2012 through October 2015 (in the right panel). The two event times in the left panel are September 2008 for the conservatorship and November 2008 for the announcement of the Federal Reserve to purchase agency MBS. The event time in the right panel is October 2013 when the U.S. version of LCR was proposed.

tee. Under the conservatorship, Fannie Mae became officially supported by the U.S. Treasury department. In contrast, Ginnie Mae has long been a wholly owned government corporation with an explicit government guarantee. Hence, the conservatorship should induce an exogenous increase in demand for Fannie Mae MBS relative to that for Ginnie Mae MBS.

In the left panel of Figure 3 we plot the yield spreads of Fannie Mae 30-year MBS (FN30y) and Ginnie Mae 30-year MBS (GN30y) against AAA corporate bonds. The time window is September 2007–September 2009. We observe that the FN30y convenience premium mostly remained lower than that of the GN30y convenience premium before the conservatorship but rose above afterwards. This pattern is consistent with a relative increase in demand for Fannie Mae MBS. The rise of the FN30y convenience premium above that of GN30y occurred shortly before September 2008, likely reflecting market expectations of the Fannie Mae rescue by the U.S. government. The fact that the movement occurred before the Fed's MBS purchase announcement on November 25, 2008, also suggests that the change was not driven by policy events other than the conservatorship (see Table 6).

Table 6: List of Policy Events

Year	Month	Event
2008	July	The Fed is authorized to lend to Fannie Mae and Freddie Mac if needed
	Sep	Fannie Mae and Freddie Mac are placed into conservatorship
	Nov	The Fed announced the QE1 purchase of agency MBS worth up to $500 billion
2009	Jan	QE1 purchases of agency MBSs officially began
	Mar	Expansion of the QE1 purchase of agency MBS by an additional $750 billion
2010	Mar	The QE1 purchases of agency MBSs ceased
2011	Sep	The Fed announced reinvestment of cash flows from agency MBS into purchases of agency MBS
2013	Jun	The fixed-income market experienced a selloff known as the "taper tantrum" that began in May
	Sep	The Fed announced QE3 purchases of agency MBSs at a pace of $40 billion per month
	Oct	The U.S. version of LCR was proposed
2014	Jul	SEC announced a plan to reform the U.S. MMF industry
	Sep	The U.S. LCR rule was finalized
	Oct	QE3 purchases of agency MBSs ceased, but reinvestments into agency MBSs continued
2015	Jan	Standard LCR banks were required to meet the standard at 80 percent,
2016	Jan	All LCR banks had to meet the requirement at 90 percent.
	Oct	The implementation deadline for the SEC's MMF industry reform
2017	Jan	The LCR requirement was fully phased in
	Apr	The largest systemically important global banks began public LCR disclosures

This table lists the major policy events involving agency MBS markets from 2008 to 2017.

To quantify this effect, we consider the following difference-in-difference regression:

$$s_{it}^{AAA-MBS} = \alpha + \beta_1 \times \text{Post-Policy}_t + \beta_2 \times \text{FN30y}_i + \beta_3 \times \text{Post-Policy}_t \times \text{FN30y}_i + \text{Controls}_t + \varepsilon_{it}, \quad (13)$$

where i = FN30y or GN30y, Post-Policy_t is a dummy for the months following September 2008, and FN30y_i is a dummy for FN30y. The coefficient β_3 captures the change in the FN30y convenience premium relative to the change in the GN30y convenience premium.

Column (1) of Panel A of Table 7 reports the regression results for the September 2007–September 2009 sample. First of all, we observe that PMMS (which is one of the control variables in 13) is significantly negative, consistent with the baseline results reported in Section 3.2 using the whole sample. Importantly, the estimated coefficient on the interaction term for Post-Policy_t and FN30y_i implies that the FN30y convenience premium increased significantly, by about 49 bps more than that of GN30y. In column (2) we report the regression results for the shorter window of March 2008–March 2009 to exclude potentially confounding events, and the estimated coefficient remains at 49 bps.

Table 7: Policy Shocks

	Conservatorship		LCR	
	(1)	(2)	(3)	(4)
	9/2007–9/2009	3/2008–3/2009	10/2012–10/2014	4/2013–4/2014
Post-Policy×FN30y	48.83**	48.61***	−20.53***	−10.08**
	(2.13)	(3.55)	(−5.81)	(−2.10)
FN30y	−7.71	−6.41	11.32***	6.64**
	(−0.61)	(−0.75)	(5.78)	(2.51)
Post-Policy	−35.92	46.32***	4.21	−9.45**
	(−0.93)	(3.52)	(1.41)	(−2.16)
PMMS	−41.47*	−84.34***	−95.82***	−142.70***
	(−1.85)	(−8.00)	(−6.13)	(−4.61)
VIX	7.67***	2.43***	3.71***	2.75**
	(10.21)	(3.32)	(7.67)	(2.05)
Slope	−12.85	35.22*	83.24***	130.77***
	(−1.49)	(1.67)	(5.59)	(4.76)
Intercept	175.16	455.68***	166.46***	258.25***
	(1.38)	(6.97)	(6.35)	(4.49)
N	50	26	50	26
R^2	0.85	0.98	0.65	0.51

Columns (1)–(2) report regressions of $s^{AAA-FN30y}$ yield spread on the dummy for FN30y, the dummy for months after the conservatorship, and their interaction term, using the sample from September 2007 to September 2009 and from March 2008 to March 2009, respectively. Columns (3)–(4) report similar regressions, but with the dummy for months after the LCR and using the sample from October 2012 to October 2014 and from April 2013 to April 2014 respectively. Robust t-statistics are reported in parentheses. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

LCR. Turning to the LCR requirement imposed by Basel III, we exploit the difference in the haircut charged to Fannie Mae MBS and to Ginnie Mae MBS as HQLA holdings. The former haircut is 15%, while the latter is zero, equivalent to the haircut assigned to excess reserves at central banks and Treasury securities; in comparison, investment-grade—including AAA-rated—corporate bonds have a haircut of 50%.) This would be followed by a relative decrease in bank demand for Fannie Mae MBS when compared with demand for Ginnie Mae MBS.

We use October 2013 when the U.S. version of LCR was proposed as the policy event time, but note that the LCR experienced progressive implementation steps so that the effects likely came about gradually; for example, the U.S. LCR rule was finalized in September 2014 and the implementation was phased in from January 2015 (see Table 6). Hence, in the right panel of Figure 3, we plot the FN30y and GN30y convenience premia from one year before to two years after the event time, i.e., October 2012–October 2015. Indeed, the level of FN30y and GN30y convenience premia began to rise two quarters after October 2013. Importantly, the FN30y convenience premium mostly remained above that of the GN30y convenience premium before October 2013 but fell below it later, which is consistent with a relative drop in demand for Fannie Mae MBS.[29]

In columns (3) and (4) of Table 7, we report results of the regression (13) with Post-Policy$_t$ defined as the dummy for the months following October 2013, for the October 2012–October 2014 sample, and for the April 2013–April 2014 sample, respectively. The estimated coefficients on the interaction term imply that relative to GN30y convenience premium, the FN30y convenience premium dropped significantly by about 10–20 bps.[30]

Overall, the analyses of conservatorship and LCR events provide supportive evidence of the safety and regulatory-constraint channels of MBS demand. One potential concern with the above estimates is that they may contain the effect of policy events, especially the conservatorship, on Fannie Mae's credit worthiness. To address this concern, we subtract the FN30y yield by the CDS spread on Fannie Mae (FNCDS) obtained from Markit. In Table A.3 we report the regression results using this CDS-adjusted yield spread for the March 2008–March 2009 sample and the July 2013–July 2014 sample. The estimated effects for the conservatorship are smaller, suggesting that the conservatorship indeed affected the market pricing of Fannie Mae creditworthiness; but the greater increase in the FN30y convenience premium over that of the GN30y convenience premium is still highly significant, around 35 bps. In contrast, the estimated coefficients on the interaction term change little for LCR, confirming that the LCR rule, which concerns regulatory constraints, does not affect the (relative) creditworthiness of Fannie Mae and Ginnie Mae.

[29]Two further points are worth mentioning. First, this movement of the FN30y convenience premium occurred between late 2013 and early 2014, which was after the March–June 2013 taper tantrum and long before the 2016 money market fund reforms; see Table 6 for major policy events. Second, Ginnie Mae and Fannie Mae MBS receive a zero and 20% risk weight respectively in Basel II capital adequacy ratio requirement introduced in 2004 (Hayre and Young, 2004), which can result in a higher demand for the former from banks. On the other hand, Fannie Mae MBS comprise the largest fraction of agency MBS market and the quality of their underlying conventional loans is higher than that of Federal Housing Administration and Veterans Affairs loans backing Ginnie Mae MBS. On balance, the convenience premia of Fannie Mae and Ginnie Mae MBS are comparable on average and one may be higher than the other under certain market conditions (see Section B.2 for further details).

[30]Using round-trip trading cost measures available between 2011 and 2015 (see Table A.1), we find that the LCR event does not affect the secondary market liquidity of FN30y relative to GN30y.

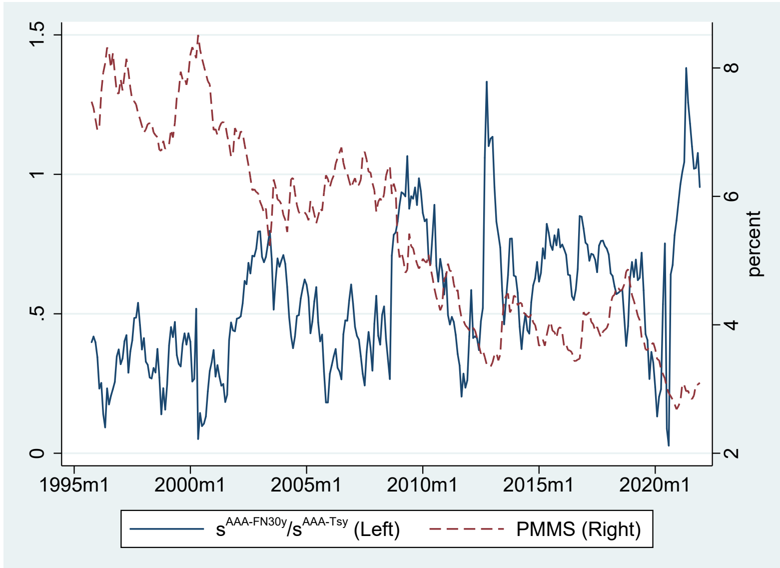

Figure 4: Ratio of AAA–MBS and AAA–Treasury Spreads

This figure plots monthly series of the ratio (left scale) of AAA-FN30y and AAA-Treasury yield spreads, as well as the 30-year mortgage rate PMMS (right scale). The sample period is October 1995–December 2021.

3.4 MBS-to-Treasury Ratio in Convenience Premium

We have thus far focused on how the MBS convenience premium (s_t^M) changes when MBS-specific demand for safe assets λ_t varies. In this section, we examine the more "structural" implications of the model, as expressed in Proposition 3: the MBS-to-Treasury convenience-premium ratio (s_t^M/s_t^B) recovers λ_t exactly and does not depend on other driving forces such as γ_t or the equilibrium quantity Q_t.

We estimate λ_t using the ratio of the AAA–MBS yield spread to AAA-Treasury yield spread, which we denote by $\hat{\lambda}_t$. Figure 4 plots monthly time series of the estimated ratio $\hat{\lambda}_t$. The mean is about 50%, consistent with the magnitude based directly on yield spreads (see Table 1). We also observe that the ratio is mostly below 50% before the 2008 crisis, but has remained above 50% since then. In several episodes, such as the 2008 crisis and the 2014 taper tantrum, the $s^{AAA-FN30y}$-to-$s^{AAA-Tsy}$ ratio rises above 100%, implying that the MBS convenience premium is even higher than the Treasury convenience premium.

One testable implication of this "structural estimation" of MBS-specific demand is that the mortgage rate, as the proxy for prepayment-driven demand for MBS, should have greater explanatory power for the ratio than for $s^{AAA-FN30y}$ currently used in Tables 2 and 3. The

Table 8: Ratio of MBS to Treasury Convenience Premia $\hat{\lambda}_t$

A: Regressions on Mortgage Rate and Federal Funds Rate

	$\hat{\lambda}$		$s^{AAA-FN30y}$	
PMMS	−0.094***	−0.104***	−4.117***	−11.337***
	(−6.427)	(−5.949)	(−2.816)	(−4.095)
Log(Debt/GDP)		−0.069		−26.016**
		(−0.972)		(−2.393)
VIX		0.001		3.254**
		(0.183)		(2.466)
Slope		0.067***		7.874***
		(3.976)		(3.027)
Intercept	1.056***	1.253***	69.106***	130.955**
	(11.246)	(3.543)	(7.489)	(2.565)
N	315	315	315	315
R^2	0.357	0.470	0.019	0.453

B: Policy Events

	Conservatorship		LCR	
	9/2007–9/2009	3/2008–3/2009	10/2012–10/2014	4/2013–4/2014
Post-Policy × FN30y	0.28***	0.15***	−0.38***	−0.18***
	(6.46)	(3.17)	(−6.00)	(−3.45)
FN30y	−0.05*	−0.04	0.21***	0.11***
	(−1.75)	(−0.82)	(3.89)	(3.38)
Post-Policy	−0.03	0.07***	0.19***	0.02
	(−0.53)	(2.72)	(3.69)	(0.41)
PMMS	−0.21***	−0.25***	−1.36***	−1.48***
	(−7.14)	(−7.89)	(−5.58)	(−4.45)
VIX	0.00***	−0.00*	0.04***	0.02*
	(3.44)	(−1.71)	(4.92)	(1.95)
Slope	−0.02	0.20***	0.96***	1.26***
	(−1.16)	(2.83)	(4.12)	(4.10)
Intercept	1.68***	1.55***	3.06***	3.15***
	(10.13)	(13.12)	(7.18)	(5.50)
N	50	26	50	26
R^2	0.87	0.93	0.71	0.64

In Panel A, the first column reports results of monthly regressions of $\hat{\lambda}_t = s_t^{AAA-FN30y}/s_t^{AAA-Tsy}$ on the 30-year mortgage rate (PMMS), while the second column adds Log(Debt/GDP), VIX, and slope of the yield curve as additional regressors. The last two columns report the regression results for $s_t^{AAA-FN30y}$, which we reproduce from Table 2 for comparison. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. The sample period is October 1995–December 2021. In Panel B, we report the difference-in-difference regressions for the conservatorship and LCR similar to those in Table 7 but using $\hat{\lambda}_t$, with robust t-statistics reported in parentheses. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

first column in Panel A in Table 8 confirms that PMMS has a significantly negative impact on $\hat{\lambda}_t$, consistent with the baseline analysis presented in Section 3.[31] Importantly, the regression R^2 is 35.7% and substantially higher than $R^2 = 1.9\%$ for $s^{AAA-FN30y}$, as reported in the third column (which we reproduce from Table 2 for the ease of comparison). The second column of Panel A in Table 8 reports regression results with Log(Debt/GDP), VIX, and the slope of the yield curve added as regressors. These additional variables are mostly insignificant, and more importantly, bring only limited improvement in R^2 relative to the uni-variate regression in the first column; this is consistent with Proposition 3 that $\hat{\lambda}_t = s_t^M/s_t^B$ is free of additional economic factors γ_t or Q_t.

Following the same logic, we also examine the effects of the conservatorship and LCR using the $s^{AAA-FN30y}$-to-$s^{AAA-Tsy}$ ratio. Specifically, the first two columns of Panel B in Table 8 report the results of the difference-in-difference regression in (13) using the ratio for the conservatorship, while the last two columns report results for the LCR. Compared with the results reported in Table 7 using $s^{AAA-FN30y}$, the regression R^2 here is similar for the conservatorship but notably higher for the LCR. One noteworthy observation is that, for the one-year window, the effects of the conservatorship and LCR on the MBS-specific demand factor $\hat{\lambda}_t$ are similar in economic magnitude, around 15% to 18%; this adds further insight into the aforementioned estimates—49 and 10 bps respectively—using $s^{AAA-FN30y}$.

Overall, these results using the MBS-to-Treasury convenience premia ratio not only confirm the effects of MBS-specific demand drivers but also provide empirical support for the widely used "structural" framework of the safe-asset convenience premium. Furthermore, by recovering the MBS-specific safe asset demand, this market-based indicator can be used to examine the economic drivers directly.

Here is one such example. Since the adjustment to the value of prepayment options is based on statistical prepayment models, the MBS-yield measure that we use contains a prepayment risk premium component. As shown by Boyarchenko et al. (2019), however, this component contributes very little to the time-series variations on which we focus. In fact, if our results were mainly driven by the prepayment risk premium channel, one would expect to find significant *negative* dependence of $\hat{\lambda}_t$ on the prepayment risk premium. In contrast, for the 1995–2010 sample period, we find a *positive* correlation (34%) between the prepayment risk premium measure calculated by Boyarchenko et al. (2019) and $\hat{\lambda}_t$. Although this finding is far from conclusive, it does point to the significant roles played by economic mechanisms

[31] Unreported panel analysis (similar to that reported in Table 5) using $\hat{\lambda}_t$ also confirms the negative effects of the mortgage rate.

beyond the prepayment risk premium, such as prepayment modeling uncertainty (Hansen and Sargent, 2001), information asymmetry (Gorton and Pennacchi, 1990), and coordination issues arising from these two forces (He et al., 2019).

3.5 Measure Expected Moneyness Using Mortgage Rate Forecasts

As mentioned in Section 3.2, using the mortgage rate PMMS itself (without subtracting expected future mortgage rate) to capture expected future moneyness likely brings about measurement errors. The panel analysis conducted in Section 3.2.3 fully controls for missing the expected future mortgage rate using time fixed effects.

Alternatively, one could construct expected future moneyness using the difference between PMMS and the forecast of future mortgage rate. One proxy for such a forecast is the monthly series of the 30-year mortgage rate forecast four or five quarters ahead, denoted as $\mathbb{E}_t[PMMS_{t+\tau}]$, from the Blue Chip Financial Forecasts (BCFF). We obtain the forecast series for the sample of October 1995–March 2015 and calculate the difference $PMMS_t - \mathbb{E}_t[PMMS_{t+\tau}]$. Notwithstanding potential measurement errors in using the mortgage rate forecast four to five quarters ahead to measure its "long-run" mean, this difference can capture the expected moneyness of production-coupon MBS to certain extent.

The first two columns of Table 9 report the results when we regress the AAA-MBS yield spread on $PMMS_t - \mathbb{E}_t[PMMS_{t+\tau}]$. The negative coefficients on $PMMS_t - \mathbb{E}_t[PMMS_{t+\tau}]$ are consistent with the baseline results using $PMMS_t$, though the statistical significance is weaker. Furthermore, in the third and fourth columns, we observe that the effects of $PMMS_t - \mathbb{E}_t[PMMS_{t+\tau}]$ on the MBS-to-Treasury ratio in convenience premia $\hat{\lambda}$ are not only negative but also statistically significant. The regression R^2 for $\hat{\lambda}$ is higher (26.9%) than that for $S^{AAA-FN30y}$ (1%), similar to the results reported in Table 8. Finally, from the last two columns of Table 9, the effects of $PMMS_t - \mathbb{E}_t[PMMS_{t+\tau}]$ on MBS issuance are also negative and significant.

The magnitudes of the coefficients are also revealing. First of all, for both the AAA-MBS yield spread and MBS issuance, the coefficients estimated using $PMMS_t - \mathbb{E}_t[PMMS_{t+\tau}]$ in time-series regressions are remarkably close to those in panel regressions of Table 5 which exploit cross-sectional identification; take MBS issuance as example, we have -4.432 in Table 9 and -4.859 in Table 5. Second, these coefficients are all in smaller magnitudes than those estimated in the baseline time-series regressions as reported in Table 2. These patterns on the magnitudes of the coefficients are consistent with the premise that both the time fixed effects in panel regressions and the measure $PMMS_t - \mathbb{E}_t[PMMS_{t+\tau}]$ are able to include

Table 9: Measure Expected Moneyness Using Mortgage Rate Forecasts

	$s^{AAA-FN30y}$		$\hat{\lambda}$		MBS Issuance	
PMMS-PMMS^{forecast}	−11.147*	−8.768	−0.252***	−0.163***	−6.890***	−4.342*
	(−1.846)	(−1.366)	(−7.574)	(−4.410)	(−3.777)	(−1.924)
Log(Debt/GDP)		9.091		0.168*		0.422
		(0.644)		(1.733)		(0.104)
VIX		4.335***		0.004		0.053
		(3.283)		(1.487)		(0.479)
Slope		7.133**		0.056***		1.961**
		(2.220)		(3.099)		(2.174)
Intercept	42.556***	−96.415	0.403***	−0.397	12.439***	6.816
	(5.524)	(−1.381)	(16.384)	(−1.091)	(10.984)	(0.463)
N	234	234	234	234	234	234
R^2	0.010	0.531	0.269	0.437	0.124	0.185

The first two columns report results of first-differenced regressions of AAA-FN30y yield spread on the 30-year mortgage rate, while the third and fourth columns report those for monthly issuance amount of FN30y MBS, using the full sample of October 1995–December 2021. The sample period is October 1995–March 1025. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

variations of the expected future mortgage rate in the estimation.

3.6 First-Differenced Regressions

Yield spreads and interest rates can be quite persistent over time; indeed, in our sample the first-order autocorrelation of $s^{AAA-FN30y}$ and $\hat{\lambda}$ is about 0.90, while that of $PMMS$ is about 0.99. Therefore one may worry that regressions using the level series may generate some spurious correlations. To help address this concern, we consider regressions using monthly changes of these two "pricing" variables (we do not consider monthly changes in issuance amount because it is already a "flow" measure); the first-order autocorrelation is only 0.03 for $\Delta s^{AAA-FN30y}$, 0.01 for $\Delta\hat{\lambda}$, and 0.24 for $\Delta PMMS$.

The first two columns of Table 10 report the results of time-differenced regressions for AAA-MBS yield spreads on PMMS, while the last two columns report the results for the MBS-to-Treasury ratio in convenience premia. As in the baseline, (changes in) PMMS have

Table 10: **First-Differenced Regressions**

	$\Delta s^{AAA-FN30y}$		$\Delta\hat{\lambda}$	
ΔPMMS	−19.877**	−32.381**	−0.196***	−0.276***
	(−2.004)	(−2.349)	(−5.473)	(−5.764)
ΔLog(Debt/GDP)		−66.670		−0.044
		(−0.490)		(−0.082)
ΔVIX		1.551***		0.001
		(2.707)		(0.836)
ΔSlope		14.338		0.099***
		(1.485)		(3.239)
Intercept	−0.189	−0.286	−0.001	−0.002
	(−0.173)	(−0.327)	(−0.166)	(−0.368)
N	314	314	314	314
R^2	0.028	0.170	0.095	0.129

The first two columns report results of first-differenced regressions of AAA-FN30y yield spread on the 30-year mortgage rate, while the third and fourth columns report those for the MBS-to-Treasury ratio in convenience premia ($\hat{\lambda}$). The sample period is November 1995–December 2021. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

significantly negative coefficients in front of (changes in) AAA-MBS yield spreads and MBS-to-Treasury ratio. Moreover, comparing the results reported in the first and third columns, we see that the explanatory power of mortgage rate for $\Delta\hat{\lambda}$ is still much higher (with R^2 equal to 9.5%) than that for $\Delta s^{AAA-FN30y}$ (with R^2 equal to 2.8%), consistent with the results in Section 3.4 (as reported in Table 8).

3.7 Additional Analyses and Robustness Checks

We conduct three sets of additional analyses and robustness checks (see Appendix B for details). In the first set of additional analyses, we present the following four robustness checks regarding the measures of MBS yield spreads.

1. We consider 15-year MBS and MBS issued by Freddie Mac and Ginnie Mae, as opposed to the Fannie Mae 30-year MBS used in the baseline analysis. The convenience premia for these alternative MBS are on average similar in magnitude to those of Fannie Mae 30-year MBS. Importantly, our main results remain robust using the yields of these

MBS; see Table A.2.

2. Our baseline analysis uses an AAA-MBS yield spread measure that directly adjusts for the duration differential between the AAA corporate bonds and Fannie Mae 30-year MBS. Alternatively, we run time series regressions of the unadjusted AAA-MBS yield spread on the mortgage rate but include the duration differential as a control variable, and find that the effect of the mortgage rate remains negative and significant. In fact, the duration differential does not have any effect if we add it to the time series regression of the baseline duration-adjusted measure, suggesting that our duration adjustment procedure works reasonably well. See Table A.3 for details.
3. As mentioned in Section 3.1, the MBS yield measures are provided by Barclays, so the prepayment option adjustment is based on its proprietary prepayment model and subject to misspecification issues. We obtain yield measures of Fannie-Mae 30-year MBS from a different major Wall Street dealer and confirm the negative effect of the mortgage rate on the AAA-MBS yield spread; see Table A.3.
4. We have followed Krishnamurthy and Vissing-Jorgensen (2012) in using the VIX and the slope of the yield curve as controls for variations in the AAA-MBS yield spread that are specific to corporate-default risk. We further consider a credit risk–adjusted $s^{AAA-FN30y}$ by subtracting the CDS spread on the North American Investment Grade bond index from the yields of AAA corporate bonds. Along the same lines, we also subtract the CDS spread on Fannie Mae from the FN30y MBS yield. Our main results remain largely unchanged using these measures; see Table A.3.

In the second set of additional analyses, we show that the effects of the mortgage rate remain significantly negative for both the sample period that excludes the 2008 crisis period and for the sample period that excludes the post-2020 COVID crisis period; see Table A.4.

Last but not least, we conduct event-study analyses regarding how the Fed's MBS purchases affect the MBS convenience premium. In particular, we compute the one-day change of the MBS-Treasury yield spread and MBS-to-Treasury ratio in convenience premia, from the day before the Fed's announcement to the announcement day. We consider the announcements in both the 2008 crisis period and 2020 COVID crisis period. As reported in Table A.5, while MBS-Treasury yield spread declined the most on the QE1 announcement day (about 45 bps), the MBS-to-Treasury ratio in convenience premia declined the most on the QE3 announcement day (about 19%). This contrast, likely due to the strong flight-to-safety into Treasury securities that should have increased the Treasury convenience premium significantly around the QE1 announcement day, further demonstrates the usefulness of our structural measure $\hat{\lambda}$ of the demand for MBS relative to Treasuries.

4 Conclusion

We conduct the first analysis of the economic role of agency MBS as safe assets. Our estimates show that the average MBS convenience premium is about half that of Treasury bonds. We further document the important effects of the prepayment, principal safety, and regulatory-constraint channels of demand on the MBS convenience premium and issuance.

The importance of agency MBS as safe assets, as documented by this paper, offers new and broad perspectives on various issues in housing finance, monetary policy, and asset pricing. For example, the celebrated safe-asset status of agency MBS should deliver important benefits to U.S. households for mortgage financing. Quantifying such benefits is important for housing-finance policies. Further, the significant effects of the mortgage rate and the federal funds rate on demand for MBS suggest a convenience-premium channel of monetary policy transmission, which is distinct from the traditional interest-cost channel (Boivin, Kiley, and Mishkin, 2010). Overall, many economic issues based on the broad perspective of agency MBS as safe assets remain to be researched.

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Appendices

A Model Proofs

In this appendix, we provide detailed proofs of the propositions posited in Section 2.2.

Proof of Proposition 1. Because $\kappa''(\cdot) > 0$, we have $\phi'(\cdot) > 0$. Taking the derivative of both sides of (11) with respect to λ_t, we have

$$ds_t^M/d\lambda_t = \gamma_t v' + \lambda_t \gamma v'' \cdot \left(M_t + \lambda_t \phi' dy_t^M/d\lambda_t\right).$$

This implies that

$$ds_t^M/d\lambda_t = \frac{\gamma_t v' + \lambda_t \gamma_t v'' M_t}{1 - \lambda_t^2 \gamma_t v'' \phi'} > 0$$

because $v'(B_t + \lambda_t M_t) + v''(B_t + \lambda_t M_t)\lambda_t M_t > 0$, $v'' < 0$ and $\phi' > 0$. For the equilibrium quantity, by Equation (10), since $\phi' > 0$ we have

$$dM_t/d\lambda_t = \phi' ds_t^M/d\lambda_t > 0.$$

□

Proof of Proposition 2. Taking the derivative of both sides of (11) with respect to B_t, we have

$$ds_t^M/dB_t = \lambda_t \gamma_t v'' \cdot \left(1 + \lambda_t \phi' ds_t^M/dB_t\right).$$

This implies that

$$ds_t^M/dB_t = \frac{\lambda_t \gamma_t v''}{1 - \lambda_t^2 \gamma v'' \phi'} < 0$$

because $v'' < 0$ and $\phi' > 0$. Moreover, since $\phi' > 0$ and $ds_t^M/dB_t < 0$, we have

$$dM_t/dB_t = \phi' ds_t^M/dB_t < 0.$$

Then, taking the derivative of both sides of (11) with respect to γ_t, we have

$$ds_t^M/d\gamma_t = \lambda_t v' + \lambda_t^2 \gamma_t v'' \phi' ds_t^M/d\gamma_t,$$

which implies that

$$ds_t^M/d\gamma_t = \frac{\lambda_t v'}{1 - \lambda_t^2 \gamma_t v'' \phi'} > 0$$

because $v' > 0$, $v'' < 0$, and $\phi' > 0$. For the equilibrium quantity, by Equation (10), we have

$$dM_t/d\gamma_t = \phi' ds_t^M/d\gamma_t > 0$$

because $\phi' > 0$ and $ds_t^M/d\gamma_t > 0$.

□

B Additional Results and Robustness Checks

We provide a number of additional results and robustness checks.

B.1 Secondary-Market Liquidity

In Table A.1 we present summary statistics for secondary-market liquidity of newly issued agency MBS. In particular, we use the TRACE dataset of agency MBS transactions from June 2011 to July 2015. We focus on so-called to-be-announced (TBA) forward contracts, which account for the bulk of agency MBS trading volume (Gao et al., 2017). A TBA contract is specified for a coupon stack (e.g., Fannie Mae 30-year MBS with a 4% coupon rate), corresponding to the coupon stack we consider in the main analyses.

In Panel A of Table A.1 we report summary statistics for the moneyness, issuance amount, and AAA–MBS yield spread for the three coupon stacks of Fannie Mae 30-year MBS with the most active issuance activities in this 2011–2015 sample. We observe that the moneyness, issuance amount, and yield spread are all very similar to those reported in Panel A of Table 5 for the full 1995–2021 sample. Hence, this 2011–2015 sample is quite representative of the cross section of newly issued MBS.

Importantly, in Panel B of Table A.1 we report summary statistics for the trading cost, trading volume, and turnover (defined as the trading volume divided by the issuance amount). We observe that the average trading costs of the three coupon stacks are similar in magnitude, all within the tight range of 1.2–1.4 bps. The average trading volume drops from $316 billion for coupon stack 1, which has the highest issuance amount, to $116 billion for coupon stack 3, which has the lowest issuance amount. The turnover, however, increases from about 14 for coupon stack 1 to about 27 for coupon stack 3. Overall, there is no material difference in secondary-market liquidity across these newly issued MBS; if anything, the highest-issuance coupon stack is less liquid than the other two.

B.2 Tenors and Agencies

Our main results focus on Fannie Mae 30-year MBS, which comprise the largest fraction of agency MBS. In this section, we present robustness checks using Freddie Mac and Ginnie Mae MBS and 15-year MBS.

In particular, in the first three columns of Panel A in Table A.2 we report results obtained by regressing the yield spreads (relative to AAA corporate bonds) of Freddie Mac 30-year MBS (FH30y), Ginnie Mae 30-year MBS (GN30y), and Fannie Mae 15-year MBS (FN15y), respectively, on the mortgage rate as well as Log(Deb/GDP), VIX, and the slope of the term structure. In the last three columns we report the regression results for the respective monthly issuance amounts. We observe that the regression coefficients are all negative and significant, much like the baseline results using FN30y.

In addition, there are some differences for these various MBS. As discussed in Section 3.3, Ginnie Mae MBS have always been explicitly backed by the U.S. government while Fannie Mae and Freddie Mac MBS featured implicit government backing before the conservatorship commenced in 2008 and have been supported by the U.S. Treasury since then. Moreover, a short tenor can mitigate the effects of prepayment, so 15-year MBS should be less subject to prepayment uncertainty than 30-year MBS. These effects imply that the convenience premium for FH30y should be similar to that for FN30y while the convenience premia for GN30y and FN15y should be higher. On the other hand, Fannie Mae 30-year MBS comprise the largest fraction of agency MBS issuance and are the most liquid in secondary-market trading (Gao et al. 2017), which can boost their convenience premium over those of other MBS. In Panel B of Table A.2 we report summary statistics for the yield spreads of FH30y, GN30y, and FN15y relative to FN30y, which are equal to the convenience premium for FN30y minus those for FH30y, GN30y, and FN15y. We observe that the average differences are all positive, but quantitatively tiny, no more than 5 bps. That is, the convenience premia for these various MBS are on average similar in magnitude.

B.3 MBS Yield Spreads

In this section, we present four additional results and robustness checks for the measures of MBS yield spreads.

First, our baseline measure $s^{AAA-FN30y}$ uses the Treasury term structure to adjust for the duration mismatch between FN30y MBS and AAA corporate bonds (see Appendix Appendix C for details). To confirm the robustness of our main results to the duration mismatch, in the first column of Table A.3 we include duration differential $DUR^{AAA-FN30y}$ in the regression of $s^{AAA-FN30y}$ as a control variable. Furthermore, in the second column we report the regression results of the raw AAA-FN30y yield spread without adjusting for duration mismatch. We observe that the regression coefficient on $Dur^{AAA-FN30y}$ is highly significant for the raw spread but is insignificant for the duration mismatch–adjusted spread, suggesting that our duration adjustment works reasonably well. Importantly, the effect of the mortgage rate remains negative and highly significant for both spread measures while controlling for the duration differential.

Second, the yields on both AAA corporate bonds and FN30y MBS used to compute the baseline measure $s^{AAA-FN30y}$ contain a credit-risk component. The former corresponds to the default of the bond-issuing firms, while the latter corresponds to the default of Fannie Mae. To make sure our main results are not driven by credit risk, we calculate a credit risk–adjusted $s^{AAA-FN30y}$ by subtracting the CDS spread on the North American Investment Grade bond index from the yields of AAA corporate bonds and subtracting the CDS spread on Fannie Mae from the FN30y MBS yield.

In the third column of Table A.3 we report the results of regressing the credit risk–adjusted $s^{AAA-FN30y}$ on the mortgage rate. We observe that the regression coefficient on the mortgage rate remains significantly negative, consistent with the baseline analysis. Furthermore, in the fourth and fifth columns we report the results of the difference-in-difference regression in Eq. (13) for the conservatorship and LCR, using the short windows similar to those used for columns (2) and (4) of Table 7. We observe that the conservatorship increased the FN30y convenience premium by 34.56 bps, notably lower than the effect without the credit-risk adjustment, which is 48.61 bps, from column (2) of Table 7. Instead, the LCR decreased the FN30y convenience premium by 8.67 bps, very close to the effect without the credit-risk adjustment, which is 10.08 bps, from column (4) of Table 7. Overall, these results confirm the robustness of our results to adjustments for credit risk.

Third, as discussed in Section 3.1, the measures of MBS yields are provided by Barclays, so the prepayment option adjustment is based on its proprietary prepayment model and subject to misspecification issues. We obtain measures of MBS yields from an alternative major Wall Street dealer, which are available from January 2000 to December 2021. In the last column of Table A.3 we report the results of regressing the alternative measure of $s^{AAA-FN30y}$ on the mortgage rate. The regression coefficients on the mortgage rate are significantly negative, similar to the baseline results.

B.4 Subsamples

In this section, we conduct robustness checks on the data sample. As shown in Figure 2, convenience premium measures experience extremely wide variations in the 2008 crisis, with the AAA-MBS yield spread reaching almost 400 bps. Moreover, MBS issuance amount experiences wide variations after the COVID-19 crisis in 2020. To ensure that our results are not driven exclusively by these crisis sample periods, in the last four columns of Table A.4 we report regression results for the sample that excludes the 2008 crisis period, defined as December 2007–June 2009 following the NBER definition of business cycles, and for the sample that excludes the period since 2020. The regression coefficients on the mortgage rate remain significantly negative, as in the baseline results.

B.5 Effects of the Federal Reserve's Asset Purchases

As mentioned in introduction, the Federal Reserve's purchases of agency MBS likely strengthen their safety status. In this section, we conduct some simple analyses of how such purchases, often known as quantitative easing (QE), affect the convenience premium of agency MBS. In particular, following the literature (Gagnon, Raskin, Remache, and Sack, 2011; Krishnamurthy and Vissing-Jorgensen, 2013), we conduct event-study analyses by computing the one-day change of the 10-year Treasury yield, MBS-Treasury yield spread, and MBS-to-Treasury ratio in convenience premia, from the day before the Federal Reserve's announcement to the announcement day (if the announcement occurred over the weekend, we use the first business day after the announcement as the announcement day).

We consider four QE announcements in the 2008 crisis period. The first is November 25, 2008, when the QE1 episode began with the Fed announcing a plan to purchase \$500 billion of agency MBS. The second is August 10, 2010, when the QE2 episode began with the Fed announcing that it would use principal payments received from its agency debt and agency MBS holdings to purchase Treasury bonds and would purchase an additional \$600 billion of long-term Treasury bonds, but no additional MBS. The third is September 21, 2011, when the maturity extension program (MEP) episode began with the Fed announcing that it would extend the maturity of its portfolio by purchasing long-term Treasury bonds and selling off short-term Treasury bonds, and importantly that it would reinvest principal payments from its holdings of agency debt and agency MBS in agency MBS. The last is September 13, 2012, when the QE3 episode began with the Fed announcing an additional purchase of $40 billion of agency MBS per month until the labor market improved.[32]. We also consider two QE announcements in the COVID crisis period. The first is March 15, 2020, when the Fed announced that it would purchase Treasury securities by at least $500 billion and agency MBS by at least $200 billion and reinvest all principal payments from its holdings of agency debt and agency MBS in agency MBS. The second is March 23, 2020 when the Fed announced that it would purchase Treasury securities and agency MBS in the amounts needed to support smooth market functioning and effective transmission of monetary policy to broader financial conditions and the economy.

For the 2008 crisis period, we observe from Table A.5 that 10-year Treasury yields declined on all four announcement days, while the MBS-Treasury yield spread declined on the QE1, MEP, and QE3 announcement days, consistent with Krishnamurthy and Vissing-Jorgensen (2013). Importantly, while the MBS-Treasury yield spread declined the most on the QE1 announcement day (about 45 bps), the MBS-to-Treasury ratio in convenience premia $\hat{\lambda}$ declined the most on the QE3 announcement day (about 19%). This contrast is likely due to the strong flight-to-safety into Treasury securities that should have increased the Treasury convenience premium significantly around the QE1 announcement day. We also observe that the MBS-Treasury yield spread increased and $\hat{\lambda}$ decreased on the QE2 announcement day, which involved purchases of Treasury securities exclusively, though the magnitudes are fairly small. Turning to the COVID period, we observe that $\hat{\lambda}$ increased on March 16 and then decreased on March 23, suggesting that the first announcement had a larger effect on agency MBS while the second announcement had a larger effect on Treasury securities.

C Details Regarding the Data and Measures

In this section, we provide details regarding the data and empirical measures. Unless discussed explicitly otherwise, the sample period is October 1995–December 2021 and we construct monthly series using the average of daily observations over a month if available.

HQLA holdings. The HQLA holdings of the three banks (JP Morgan, Wells Fargo, and Citigroup) reported in Figure 1 are obtained from their LCR disclosure reports at the end of 2021. We choose these three banks because their LCR reports are among the very few that separate the amounts of excess reserves from Treasury securities (both are so-called level-1 assets with zero haircut). The estimates of Treasury securities are potentially subject to upward bias because they may include Ginnie Mae securities and foreign sovereign bonds, whereas the estimates of agency MBS are potentially subject to both upward bias

[32]Each QE episode usually involves multiple announcements. For example, in the QE1 episode, Chairman Bernanke's December 1, 2008, speech indicated the Fed's intention to purchase longer-term Treasury securities and the Fed's March 19, 2009, announcement to purchase up to $1.25 trillion of agency MBS, $200 billion of agency debt and $300bn of long-term Treasury securities. Our analyses focus on the first announcement of a QE episode, which has been shown to feature the largest asset price responses (Gagnon et al., 2011; Krishnamurthy and Vissing-Jorgensen, 2013).

from including agency debt and downward bias from missing Ginnie Mae MBS. In comparison, Ihrig, Kim, Vojtech, and Weinbach (2019) conduct a detailed calculation of HQLA holdings and find that for 15 bank-holding companies (including JP Morgan, Wells Fargo, and Citigroup) with $250 billion or more in total assets or $10 billion or more in on-balance sheet foreign exposures, agency MBS account for about 40% of the total HQLA holdings at the end of 2016, a number that is much larger than our estimate (10%).

Repo outstanding balance. The outstanding balances of tri-party repos reported in Figure 1 are obtained from the Federal Reserve Bank of New York.[33] They are calculated based on snapshots of the market on the seventh business day of each month using data from the two tri-party repo-clearing banks, Bank of New York Mellon and JP Morgan Chase. The amount of Treasury collateral is a sum of the "US Treasuries Strips" and "US Treasuries excluding Strips." The amount of agency MBS collateral is the sum of the "Agency MBS" and "Agency CMOs." The amount of other collateral is the sum of "ABS Investment Grade," "CMO Private Label Investment Grade," "Corporates Investment Grade," "Money Market," and "Municipality Debt."

Measures of convenience premia. The yields for 30-year production-coupon MBS guaranteed by Fannie Mae (FN30y), Freddie Mac (FH30y), and Ginnie Mae (GN30y) and for 15-year production-coupon MBS guaranteed by Fannie Mae (FN15y) are obtained from the Bloomberg Barclays total return index series. They are adjusted for the value of prepayment options based on an interest rate model (under the risk-neutral measure) and a prepayment model (under the physical measure). The yield of AAA corporate bonds is also obtained from the Bloomberg Barclays total return index series. To adjust for the duration mismatch between AAA corporate bonds and agency MBS, we obtain their respective duration measures (the option-adjusted duration is used for agency MBS), interpolate two yields with maturities equal to the AAA corporate and agency MBS durations using the Treasury yield curve of Gurkaynak et al. (2007), and subtract the difference between these two interpolated yields from the raw AAA-MBS yield spread. The resulting yield spread measure is our duration-matched AAA-MBS yield spread $s^{AAA-MBS}$. The yield spread between AAA corporate bonds and duration-matched Treasuries and the negative of the OAS of agency MBS to Treasuries, both obtained directly from the Bloomberg Barclays index series, are denoted as $s^{AAA-Tsy}$ and $s^{MBS-Tsy}$, respectively. In addition, to adjust for default risk, we obtain CDS spreads on Fannie Mae and NAIG from Markit.

To measure convenience premia for repo contracts, we obtain one-month general collateral (GC) repo rates on agency MBS from Bloomberg. These repo rates are available starting in 2004. We also obtain one-month GC repo rates for Treasury securities from a Wall Street dealer. As the benchmark, we use one-month certificate of deposit (CD) rates from FRED, which was provided in the Federal Reserve's H.15 release until June 2013 and then was discounted. We append the series with 3-month CD rates computed by the Organization for Economic Co-operation and Development, also retrieved from FRED (the results remain similar using the one-month Libor rate as the benchmark). The spreads between CD rates

[33]The data are disclosed to the public at https://www.newyorkfed.org/data-and-statistics/data-visualization/tri-party-repo.

and MBS repo rates and between CD rates and Treasury repo rates, denoted by CD-MBS and CD-Treasury repo spreads, are used to measure convenience premia for MBS and Treasury repo contracts.

Supply variables. The monthly new issuance amount of 30-year production-coupon Fannie Mae MBS is obtained from Fannie Mae disclosure reports, historically collected by eMBS. Data on the ratio of outstanding U.S. government debt to GDP are obtained from FRED, specifically from the seasonally adjusted quarterly series of "Federal Debt Held by the Public as Percent of Gross Domestic Product" (FYGFGDQ188S), first constructed by the Federal Reserve Bank of St. Louis in October 2012 based on data obtained from the U.S. Office of Management and Budget. Like Nagel (2016), we interpolate the quarterly series in linear fashion to obtain monthly measures.

Time series factors. The mortgage rate series are obtained from the Freddie Mac primary mortgage market survey for fixed-rate mortgage loans. They are available at weekly frequency and the monthly measure is constructed as the average of weekly observations over a month. The federal funds target rate series is obtained from FRED, with the point target rate prior to December 16, 2008, and the target range afterwards for which the mid-point is used. The VIX series is obtained from the Chicago Board Options Exchange, whereas Treasury yields are those constructed by Gurkaynak et al. (2007) based on which the slope of the yield cure is measured as the difference between the 10-year zero-coupon rate and the 3-month T-bill rate.

Cross section of newly issued MBS. We obtain the coupon stack–level series of yields on Fannie Mae 30-year MBS from the Bloomberg Barclays index series and the corresponding series of monthly issuance amounts from eMBS. For each month, we rank all coupon stacks by their issuance amounts and retain the top three coupon stacks. We obtain the current coupon rate—the par coupon rate for a synthetic par TBA contract obtained by interpolating TBA prices trading near par—from Barclays and compute the moneyness of each coupon stack as the difference between its coupon rate and the current coupon rate.

Data on MBS transactions and liquidity measures. We use MBS transaction data obtained from the Financial Industry Regulatory Authority (FINRA) through its Trade Reporting and Compliance Engine (TRACE) that became available after May 2011 (we have access to the data through July 2015). Each trade record includes the trade type, agency, loan terms, the security coupon rate, the price, par value, the trade date, and the settlement month, among other features for each trade. We apply a number of standard procedures to clean the data; see An and Song (2021) for details. We retain the outright Fannie Mae 30-year TBA transactions executed between dealers and customers.

We compute the total par dollar volume of TBA trades for each coupon cohort in each month, which usually spans a period running from the day after the TBA settlement day in the previous month to the settlement day in the current month. We divide TBA trading volume by the issuance amount to obtain the measure of turnover. We further calculate a round-trip transaction cost measure as the difference between the volume-weighted average price of dealers' sales to customers and the volume-weighted average price of dealers' purchases from customers, using all transactions of each coupon stack in each month. For this calculation, we require that at least two transactions—one sale of dealers to customers and one purchase of dealers from customers—be available on a given day; otherwise, we exclude stand-alone transactions.

Mortgage rate forecasts. The BCFF surveys collect forecasts from a large number of professional economists at leading financial institutions including banks, broker-dealers, and consulting firms. The surveys are conducted at the monthly frequency, usually on the first two business days of each month and published on the tenth (other surveys such as the Survey of Professional Forecasters and Livingston Survey of the Federal Reserve Bank of Philadelphia are conducted at a quarterly or semi-annual frequency). The forecasts of the mortgage rate for the current quarter and one to five quarters ahead are provided. For example, the January 2005 survey contains forecasts from the first quarter of 2005 to the first quarter of 2006. For each forecast horizon, we use the median forecast across different forecasters as the consensus. We then compute the simple average of the consensus forecasts across forecast horizons as the mortgage rate forecast. Our sample period runs from October 1995 through March 2015, during which there are about 50 professional forecasters involved each month on average.

Table A.1: Liquidity Metrics

A: Summary of Moneyness, Issuance, and Convenience Premium									
	Moneyness			Issuance			$s^{AAA-MBS}$		
Issuance Rank	mean	p25	p75	mean	p25	p75	mean	p25	p75
1	0.133	0.011	0.287	19.239	13.378	22.650	44.90	32.69	58.89
2	0.253	-0.213	0.630	8.978	5.297	11.889	40.96	28.26	50.75
3	0.343	-0.349	0.864	2.913	1.929	3.659	37.26	27.96	50.45
B: Summary of Liquidity Metrics									
	Trading Cost			Trading Volume			Turnover		
Issuance Rank	mean	p25	p75	mean	p25	p75	mean	p25	p75
1	1.36	0.79	1.75	316.43	262.81	379.87	17.94	13.99	20.28
2	1.20	0.49	1.63	215.87	175.54	243.04	27.61	19.70	30.12
3	1.27	0.62	1.84	115.85	77.09	149.01	44.86	27.20	53.87

Panel A reports summary statistics (the mean, 25th percentile, and 75th percentile) of the moneyness (equal to MBS coupon rate minus current coupon rate in percentage), monthly issuance amount (in \$billion), and yield spread relative to AAA corporate bonds (in bps), for each of the three coupon stacks of Fannie Mar 30-year MBS with the most active issuance activities. The coupon stack with issuance rank equal to 1 (3) refers to the coupon stack that has the largest (smallest) issuance amount in each month. Panel B reports summary statistics of the trading cost (in cents per \$100 par value), trading volume (in \$billion), and turnover (equal to trading volume divided by issuance amount). The sample period is June 2011–July 2015.

Table A.2: Agencies and Tenors

A: Regressions						
	$s^{AAA-MBS}$			MBS Issuance		
	FH30y	GN30y	FN15y	FH30y	GN30y	FN15y
PMMS	-10.383***	-11.622***	-3.963*	-3.567***	-0.165	-2.220***
	(-3.541)	(-4.467)	(-1.881)	(-5.866)	(-0.568)	(-3.340)
Log(Debt/GDP)	-35.922***	-37.402***	3.749	-9.710***	-1.818	-7.288**
	(-2.972)	(-3.678)	(0.425)	(-4.253)	(-1.567)	(-2.434)
VIX	2.858**	2.646**	2.501**	0.026	0.159***	0.054
	(2.051)	(2.376)	(2.241)	(0.308)	(3.656)	(0.910)
Slope	9.362***	5.528**	3.973*	0.223	1.002***	0.789***
	(3.038)	(2.209)	(1.679)	(0.516)	(3.645)	(3.473)
Intercept	165.401***	192.499***	-8.727	67.714***	5.883	40.738***
	(3.044)	(4.208)	(-0.200)	(5.651)	(0.970)	(2.745)
N	314	314	314	261	261	261
R^2	0.388	0.391	0.354	0.232	0.487	0.369
B: Summary Statistics of Yield Spreads to FN30y						
	mean	sd	p25	p50	p75	
$s^{FH30y-FN30y}$	1.32	15.25	-5.01	0.00	3.68	
$s^{GN30y-FN30y}$	4.81	11.52	1.28	2.50	3.95	
$s^{FN15y-FN30y}$	2.27	14.15	-7.35	-0.57	7.77	

The first three columns of Panel A report results of monthly time series regressions of yield spreads of FH30y, GN30y, and FN15y MBS relative to AAA corporate bonds, respectively, on 30-year mortgage rate, while the last three columns report those for the monthly issuance amount. Panel B reports summary statistics of the yield spreads of FH30y, GN30y, and FN15y MBS relative to FN30y MBS. Robust t-statistics based on Newey and West (1987) standard errors using the rule-of-thumb bandwidth choice are reported in parentheses. The sample period is October 1995–December 2021 for yield spreads but January 1998–October 2019 for issuance amounts. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

Table A.3: Duration, Credit Risk, and Dealer Prepayment Model

	Duration Adjustment		Credit-risk-adjusted			Alternative
	$s^{AAA-FN30y}$	Unadjusted spread	$s^{AAA-FN30y}$			Dealer
PMMS	-11.910***	-17.311***	-21.390*	-81.33***	-166.70***	-8.933***
	(-4.764)	(-5.613)	(-1.956)	(-8.32)	(-3.96)	(-3.612)
$DUR^{AAA-FN30y}$	1.516	11.340***				
	(0.677)	(4.550)				
Log(Debt/GDP)	-31.773**	-60.296***	-100.075***	94.16	-181.36	12.698
	(-2.427)	(-3.832)	(-3.578)	(1.40)	(-1.09)	(0.555)
VIX	3.244**	3.513***	4.710***	2.41***	3.56***	3.695***
	(2.431)	(2.876)	(7.088)	(3.29)	(3.26)	(2.927)
Slope	8.854***	21.055***	-0.211	37.16*	156.50***	2.136
	(3.232)	(6.742)	(-0.082)	(1.67)	(4.20)	(1.022)
Post-Policy				28.46**	-8.01	
				(2.24)	(-1.52)	
FN30y				44.92***	44.21***	
				(6.14)	(24.46)	
Post-Policy×FN30y				34.56***	-8.67**	
				(2.72)	(-2.29)	
Intercept	151.549**	265.297***	400.655**	91.11	1,055.21	17.178
	(2.465)	(3.654)	(2.517)	(0.35)	(1.45)	(0.761)
N	315	315	123	26	25	242
R^2	0.455	0.583	0.740	0.98	0.91	0.504

The first two columns report results of monthly time series regressions of duration mismatch–adjusted ($s^{AAA-FN30y}$) and raw AAA-FN30y yield spread on 30-year mortgage rate and duration differential of AAA corporate bonds and FN30y MBS. The third column reports regressions of credit risk–adjusted AAA-FN30y yield spread on 30-year mortgage rate, while the fourth and fifth columns report the different-in-difference regressions also using the credit risk–adjusted AAA-FN30y yield spread for the conservatorship and LCR. The sixth column reports the regression result for the AAA-FN30y yield spread computed using the MBS yield from an alternative dealer. All regressions include Log(Debt/GDP), VIX, and slope of the term structure. The sample period is October 1995–December 2021 for the first two columns, October 2003–February 2016 for the third column, March 2008–March 2009 for the fourth column, April 2013–July 2014 (we extend the end month from April 2014 to July 2014 because Fannie Mae CDS has missing observations in several months after October 2013) for the fifth column, and January 2001 to February 2021 for the last column. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

Table A.4: Subsamples

	Exclude the 2008 Crisis		Exclude Post-2020	
	$s^{AAA-FN30y}$	MBS Issuance	$s^{AAA-FN30y}$	MBS Issuance
PMMS	-7.604***	-7.837***	-7.974***	-6.622***
	(-4.632)	(-8.199)	(-4.693)	(-8.872)
Log(Debt/GDP)	-15.288**	-10.912**	-14.438**	-17.142***
	(-2.020)	(-2.524)	(-2.045)	(-4.418)
VIX	0.580*	0.533***	0.846*	0.161
	(1.727)	(2.940)	(1.911)	(1.353)
Slope	5.093***	-1.240	4.250***	0.189
	(3.877)	(-1.606)	(3.452)	(0.348)
Intercept	120.431***	95.372***	115.748***	116.063***
	(3.401)	(4.778)	(3.547)	(6.092)
N	296	296	272	272
R^2	0.348	0.496	0.373	0.508

The first two columns report results of first-differenced regressions of AAA-FN30y yield spread on 30-year mortgage rate, while the third and fourth columns report those for monthly issuance amount of FN30y MBS, using the full sample of October 1995–December 2021. The fifth and sixth columns report regressions of the levels of AAA-FN30y yield spread and issuance amount, respectively, using the sample excluding the 2008 crisis period (December 2007–June 2009), while the seventh and eight columns report those using the sample through December 2012. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75N^{1/3}$ are reported in parentheses. Significance levels: *** for $p < 0.01$ and ** for $p < 0.05$, and * for $p < 0.1$, where p is the p-value.

Table A.5: Effects of the Federal Reserve's Announcements of Asset Purchases

Events	Date	10-year Treasury	MBS-Treasury	$\hat{\lambda}$
QE1	November 25, 2008	-21.38	-45.486	0.111
QE2	August 10, 2010	-6.87	0.791	-0.015
MEP	September 21, 2011	-8.37	-3.687	0.041
QE3	September 13, 2012	-2.92	-11.007	0.191
COVID	March 16, 2020	-22.76	-6.062	0.159
	March 23, 2020	-20.38	9.057	-0.102

This table reports the dates, as well as one-day changes of the 10-year Treasury yield (in bps), MBS-Treasury yield spread (in bps), and MBS-to-Treasury ratio in convenience premia, from the day before the Federal Reserve's announcement of asset purchases (QE) to the announcement day. We consider four event days associated with respective asset purchase programs in the 2008 financial crisis period and two announcement days in the 2020 COVID crisis period.