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ABSTRACT

Measured as yield spreads against AAA corporate bonds, the convenience premium of agency MBS averages 47 basis points over 1995 - 2021, about half of the long-term-Treasury convenience premium. Both MBS convenience premium and issuance amount depend on mortgage rate negatively, consistent with a prepayment-driven demand channel. This negative dependence contrasts strikingly with the positive dependence of the MBS-repo convenience premium on the level of interest rates as implied by the “opportunity cost of money” hypothesis. The placing of agencies into conservatorship in 2008 and introduction of liquidity coverage ratio in 2013 affect convenience premium significantly, consistent with the safety and regulatory-constraint channels of MBS demand. Based on “structural” restrictions in standard models, the ratio of MBS to Treasury convenience premia pinpoints the time-varying MBS-specific safe asset 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." Which assets serve as safe assets in the economy?[1] The literature has mainly focused on reserves at central banks and Treasury securities as public safe assets (e.g., Krishnamurthy and Vissing-Jorgensen, 2012; Greenwood, Hanson, and Stein, 2015; Nagel, 2016), and bank deposit, commercial paper, and repurchase agreement as private safe assets (e.g., Sunderam, 2014; Carlson, Duygan-Bump, Natalucci, Nelson, Ochoa, Stein, and den Heuvel, 2016; Kacperczyk, Pérignon, and Vuillemey, 2019). In this paper, we analyze the distinctive role and economic channels of agency mortgage-backed securities (MBS) 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); for comparison, the outstanding balance of Treasury securities, corporate bonds, and municipal bonds, is 23, 10, and 4 trillion, respectively. Importantly, there is ample anecdotal evidence for the nature and role of agency MBS as safe assets. First, with principal balance essentially backed by the U.S. government, the safety of agency MBS is close 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,[2] is about half the fraction of Treasury securities, much higher than the fraction of all other securities (about 0.3%). Third, agency MBS are widely used as collateral for repo financing, which can cushion temporary liquidity shocks conveniently. 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, MBS are a critical component of

[1]The concept of safe asset is elusive, often used with an operational definition (Caballero, Farhi, and Gourinchas, 2017). The theoretical literature has modelled several economic channels, such as Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2015) on information sensitivity, and He, Krishnamurthy, and Milbradt (2019) and Farhi and Maggiori (2017) 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

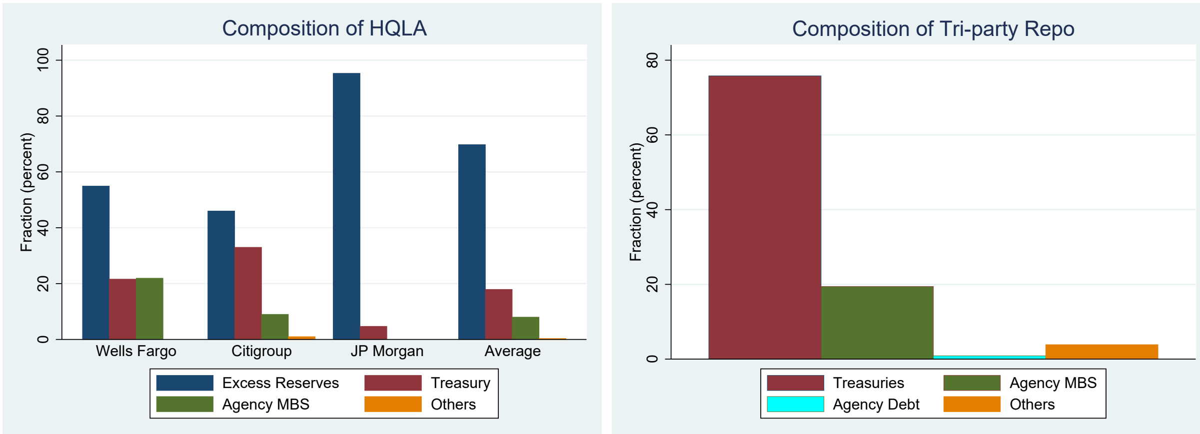

Figure 1: HQLA and Repo

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 respective average weighted (by haircut) amount of HQLA is $554, 383, and 738 billion. 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) of tri-party repo outstanding balance as of December 2021. The total amount of outstanding tri-party repo is $3.45 trillion. Appendix C provides details of the measures.

monetary policy operations, experiencing purchases by the Federal Reserve (Fed) during the 2008 financial crisis and 2020 COVID-19 crisis, which likely strengthen their safety status.

Motivated by these anecdotal evidence, this paper analyzes the economic channels of agency MBS as safe assets. We start our analysis in Section 2 by formulating an economic framework of MBS convenience premium based on the standard approach in the literature. In particular, the demand for safe assets is modeled through a money-in-the-utility function (Krishnamurthy and Vissing-Jorgensen, 2012; Nagel, 2016). Moreover, we allow the MBS supply to be endogenously determined in equilibrium, similar to Sunderam (2014) who studies commercial paper. Our main analyses consist of empirical tests of equilibrium implications derived from this standard framework, specifically, on how MBS convenience premium and supply depend on safe asset demand. What distinguishes our analyses from the existing studies on safe assets is that we focus on the demand for MBS *relative* to other safe assets like Treasury securities rather than the demand for *all* safe assets (e.g., those that vary with

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).

flight-to-safety in recessions or changing opportunity costs of money). These MBS-specific demand drivers include prepayment, principal safety, and regulatory constraint.

To conduct empirical tests on these MBS-specific demand drivers, we use AAA corporate bonds as the benchmark asset following Krishnamurthy and Vissing-Jorgensen (2012) and measure the convenience premium of newly-issued 30-year Fannie Mae MBS using the AAA-MBS yield spread.[4] Following the literature (Gabaix, Krishnamurthy, and Vigneron, 2007; Boyarchenko, Fuster, and Lucca, 2019; Song and Zhu, 2019), we adjust the MBS yields for the value of prepayment options that U.S. mortgage borrowers have based on prepayment models of MBS dealers. We also adjust the AAA-MBS yield spread for duration mismatch between the corporate bonds and MBS based on their durations. Using monthly series of the resulting yield spread measure, we find that MBS convenience premium averages 47 basis points (bps) from 1995 to 2021, about half 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 different coupon rates are issued at the same time (we take advantage of this panel structure in the later analysis); the aforementioned numbers are for the MBS with the highest issuance amount each month, often known as "production coupon" stack.[5]

Using these measures, our first set of main analyses focuses on the prepayment-driven MBS demand (in Section 3.2) . We measure the prepayment incentive using the rate of 30-year mortgages that back the newly-issued 30-year MBS; this rate captures the expected "moneyness" in the future.[6] 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 other safe assets that are not subject to prepayment. One could micro-found this safe-asset demand for MBS based on either prepayment modeling uncertainty (Hansen and Sargent, 2001), information asymmetry (Gorton and Pennacchi, 1990), or coordination issues emanated from the these two forces (He et al., 2019).

Our testing hypothesis therefore is that the higher the mortgage rate, the lower the MBS

[4]Fannie Mae 30-year MBS are the largest among different agencies and different tenors: Fannie Mae MBS account for more than 40% of the total agency MBS outstanding, while 30-year MBS account for over 80%; see Liu, Song, and Vickery (2021).

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

[6]The standard moneyness measure, defined as the difference between the underlying mortgage rate of the MBS and the prevailing mortgage rate, is (close to) zero for newly-issued MBS by default. It is nonzero for seasoned MBS because of interest rate variations.

demand, and the higher the AAA-MBS yield spreads and MBS issuance amount. Indeed, monthly time series regressions over 1995-2021 show that a one-standard-deviation increase in mortgage rate decreases the MBS convenience premium by about 18 bps and the monthly issuance amount by about $12 billions. We also find that Treasury supply (as measured by the U.S. debt-to-GDP ratio similar to Krishnamurthy and Vissing-Jorgensen, 2012) negatively affects MBS convenience premium and "crowds out" MBS issuance, consistent with the substitutability between MBS and Treasury securities in satisfying safe asset demand.

We conduct further analyses to understand the effects of the prepayment-driven MBS demand in comparison with the "opportunity cost of money" channel (Sunderam, 2014; Nagel, 2016). We first show that similar to mortgage rate, which is relatively *long-term*, the *short-term* federal funds rate also *negatively* affects MBS convenience premium. This result is 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 theory of "opportunity costs of money" fails for MBS; in fact, when looking at short-term repo backed by long-term agency MBS, we recover the *positive* dependence between MBS repo convenience premium and federal funds rate. These findings not only differentiate our effects of the prepayment-driven MBS demand 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 time series regressions we use may miss some "unobservable" aggregate factors that drive MBS convenience premia, confounding our estimates. We conduct two analyses to address this concern. First, we confirm the significant negative effect of mortgage rate on MBS convenience premium and issuance using panel data of newly-issued MBS; the existence of multiple MBS coupon stacks allows us to include time series fixed effects in the regression.[7] The cross-sectional identification embedded in the panel regression hence helps "rule in" the channel of prepayment-driven MBS demand. Second, we examine certain specific aggregate shocks in detail; one such leading example is unobservable negative "demand" shocks (say from reduced appetite of foreign investors) that would cause a *lower* MBS convenience premium, which, if passing on to mortgage borrowers, leads to a *higher* mortgage rate. The aforementioned effects of federal funds target rate on MBS convenience premium and issuance alleviate this concern; even if the Fed responds in an endogenous way, it would cut rates downward to suppress increasing mortgage rate and hence generate a negative relation

[7]These coupon stacks are all newly-issued MBS and have no difference in secondary market liquidity. For example, their average trading costs are in the tight range of 1.2-1.4 cents per $100 par value; see Section 3.2.3 for details.

between mortgage rate and federal funds target rate. But this is opposite to the positive relation the data reveals.

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 events as quasi-natural experiments to demonstrate the effects. The first is the placing of Fannie Mae (and Freddie Mac) into conservatorship on September 6, 2008 that is officially backed by the U.S. Treasury department. Before the conservatorship, they were private entities with only implicit U.S. government support.[8] The conservatorship would naturally induce an increase in the demand for MBS of Fannie Mae 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 assigns Fannie Mae and Ginnie Mae MBS a haircut of 15 and zero percent, respectively, in computing the amount of HQLA holdings. This would induce an decrease in banks' demand for Fannie Mae MBS relative to Ginnie Mae MBS.

We conduct standard different-in-difference analyses on MBS convenience premia using the short windows around the policy shocks (we do not examine issuance amount because supply shifts are challenging to detect in such a short window). Consistent with an increase in demand for the Fannie Mae MBS relative to that of Ginnie Mae, we find that the yield spread of Fannie Mae MBS mostly stayed lower than that of Ginnie Mae before the conservatorship, but jumped above afterwards. Difference-in-difference regressions using the sample of one-year event window quantify the effects of conservatorship to be about 49 bps. To address the concern 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, but it is still statistically significant and economically large, about 35 bps. Similar analyses show that the effect of LCR is about 15 bps. Interestingly, the LCR effect shows no change adjusting for Fannie Mae CDS, consistent with the LCR event working as a regulatory constraint shock rather than a shock to the principal safety.

Our last set of main analyses (in Section 3.4) examine a "structural" implication of the standard model framework we use. Specifically, in the model, the ratio of MBS convenience premium to Treasury convenience premium *exactly* uncovers the demand for MBS relative to other safe assets and is free from other driving forces (like the demand of all safe assets or its

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

equilibrium quantity). A testable implication is that, relative to the AAA-MBS yield spread, this ratio is an ideal measure for the MBS-specific demand and should exhibit a much greater explanatory in our main regressions. Indeed, we find that the regression R^2 on mortgage rate is 35% for the ratio, substantially higher than that for the AAA-MBS yield of only about 2%. This not only delivers empirical support to the widely-used "structural" framework of safe asset convenience premium, but also provides a measure that quantitatively captures the convenience benefit of agency MBS (relative to Treasury securities).

Because the adjustment for the value of prepayment options is done based on statistical prepayment models, the MBS yield measure we use contains a (non-interest-rate) prepayment risk premium component. However, as shown by Boyarchenko et al. (2019), this component contributes very little to the time series variations we focus on. In fact, we find that the ratio of MBS to Treasury convenience premium—the "structural" measure of the MBS-specific safe asset demand—cannot be explained by the prepayment-risk-premium measure of Boyarchenko et al. (2019); if anything, it goes in the opposite direction. Overall, we do not claim victory in totally separating convenience premium from risk premium, which is a challenging task for the safe-asset literature; instead, we view our analyses as a starting point to bring in the safe-asset perspective to agency MBS pricing.

Throughout all the analyses, we follow Krishnamurthy and Vissing-Jorgensen (2012) to include the VIX and slope of the yield curve as controls for the variations of the AAA-MBS spread that are specific to corporate default risk. In Section 3.5, we also confirm our results when we adjust the AAA-MBS spread using the CDS spread of corporate bonds, as well as the CDS spread of agencies that controls for agency default. Additional robustness checks include using MBS yields from different dealers who use different prepayment models, first-differenced regressions, and so on.

Our paper contributes to both the literature on safe assets' supply, demand, and convenience premia,[9] and the literature on agency MBS pricing.[10] To the best of our knowledge, the safe asset literature has not examined the economic drivers of agency MBS. In the MBS pricing literature, several recent studies investigate the cross-sectional variation of prepay-

[9]Among others, these include early studies by Bansal and Coleman (1996), Duffee (1996), and Longstaff (2004) and recent studies by Gorton, Lewellen, and Metrick (2012), Xie (2012), Krishnamurthy and Vissing-Jorgensen (2015), Bansal, Coleman, and Lundblad (2011), Du, Im, and Schreger (2018), Fleckenstein and Longstaff (2020), Jiang, Krishnamurthy, and Lustig (2019), Infante (2020), He, Nagel, and Song (2021) and He and Krishnamurthy (2020); see Gorton (2017) and Caballero et al. (2017) for broad surveys on safe assets.

[10]Recent studies include Gabaix et al. (2007), Duarte, Longstaff, and Yu (2007), Chernov, Dunn, and Longstaff (2018), Boyarchenko et al. (2019), Carlin, Longstaff, and Matoba (2014), Krishnamurthy and Vissing-Jorgensen (2013), Chen, Liu, Sarkar, and Song (2020), Diep, Eisfeldt, and Richardson (2021), and Fusari, Li, Liu, and Song (2021) among others.

ment risk premium (e.g., Gabaix et al., 2007; Boyarchenko et al., 2019; Diep et al., 2021). We complement them by examining the time-series dimension and convenience premium of agency MBS associated with their safe-asset status. Moreover, our analysis on MBS repo complements Bartolini, Hilton, Sundaresan, and Tonetti (2011) and Song and Zhu (2019) who study financing markets of agency MBS.[11]

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 (MIU) approach (Krishnamurthy and Vissing-Jorgensen, 2012; Nagel, 2016).[12] In particular, a representative economic 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 economic agent's consumption at date t, and

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

is the total amount of real liquidity holding with M_t and B_t the *real* balances of MBS and Treasury securities, respectively. The "convenience" benefit that the economic agent derives

[11]By studying agency MBS as liquid and safe assets, our analysis is also related to the recently expanding literature of 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), Schultz and Song (2019), and Li and Song (2019), among others.

[12]This MIU framework of Sidrauski (1967) is widely used in monetary economics. Alternative frameworks, including Baumol (1952), Tobin (1956), Clower (1967), Lucas (1980), Kiyotaki and Wright (1989), and Brock (1974) among others, emphasize the transaction role of money that are arguably more micro-founded. Yet, some of these frameworks are actually equivalent to a MIU function (Brock, 1974; Feenstra, 1986). See Walsh (2017) for more details.

from the asset balance Q_t—which is in the same spirit of money balance—is modelled as a reduced-form function $v(Q_t)$, with $v'(\cdot) > 0$ and $v''(\cdot) < 0$. Since we focus on the spread between nominal assets, our model is cast in real terms and hence abstracts away from inflation issues.[13]

The term γ_t in Eq. (1) captures time-varying demand for *all* safe assets. For example, γ_t would increase when investors engage in flight-to-safety in economic downturns. In contrast, λ_t in Eq. (2) captures time-varying demand for MBS *relative to other* safe assets—Treasury securities specifically in the model. It is driven by the distinct features of MBS relative to Treasury securities—including prepayment, implicit government backing, and regulatory treatment as will be detailed in the following—that affect the convenience benefits of MBS as liquidity holdings.

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.[14] The first order condition for c_t is

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

while the first order condition for M_t is

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

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

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

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

[14]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., liquidity holdings 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.

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.

To derive conditions on the convenience premia, we consider, for simplicity, one-period Treasuries and MBS with $P_{t+1}^M = 1$ and $P_{t+1}^B = 1$. Define the MBS yield as $r_t^M \equiv -\ln\left(P_t^M\right)$. Then we have

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

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 of MBS as

$$s_t^M \equiv r_t - r_t^M = \lambda_t \gamma_t v'(Q_t). \tag{8}$$

Similarly, the convenience premium for Treasury securities is defined as

$$s_t^B \equiv r_t - r_t^B = \gamma_t v'(Q_t). \tag{9}$$

Safe asset supply. We assume that Treasury supply B_t is exogenously determined by the government, similar to Krishnamurthy and Vissing-Jorgensen (2012). The MBS supply M_t is, instead, endogenously determined by banks who intermediate between mortgage borrowers and representative economic agents (who are savers). Specifically, there is a continuum of banks of mass one, who securitize mortgage loans from mortgage borrowers as MBS, which they then sell to economic agents. That is, banks essentially serve as intermediaries between loans that economic agents provide to mortgage borrowers.[15] For modeling simplicity, we

[15]The setup with one household sector (economic agents) lending to another household sector (mortgage borrowers) through banks is widely used in quantitative macro models with a housing sector, where borrowers are assumed to have a lower time discount factor than savers (see Davis and Nieuwerburgh (2015) and Piazzesi and Schneider (2016) for surveys on this literature). In our setup, mortgage borrowers are assumed to be extremely impatient for simplicity: they statically take out mortgage loans rather than solving a fully dynamic optimization problem.

assume that banks have monopoly market power (see Scharfstein and Sunderam (2017) for empirical evidence on 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 up to r_t (maximum willingness-to-pay), while by Eq. (8), economic agents require a rate of r_t^M. Therefore, given a quantity of M dollars of MBS, the total gain is $M_t(r_t - r_t^M) = M_t s_t^M$, which goes to the (monopolistic) banking sector. We further assume that banks have a private cost $\kappa(M_t)$ with $\kappa'(\cdot) > 0$ and $\kappa''(\cdot) > 0$ similar to Sunderam (2014). Banks solve $\max_{M_t} \left\{ s_t^M M_t - \kappa\left(M_t\right) \right\}$ with the following first order condition:

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

Because $\kappa''(\cdot) > 0$, M_t is a monotonically increasing function of s_t^M, all else equal.

Equilibrium. To summarize the equilibrium, we define $\phi\left(\cdot\right) \equiv \left[\kappa'\left(\cdot\right)\right]^{-1}$, and from Eq. (10) we have

$$M_t = \phi\left(s_t^M\right). \tag{11}$$

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

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

$$s_t^B = \gamma_t v'\left(Q_t\right), \tag{13}$$

where $Q_t = B_t + \lambda_t \phi\left(s_t^M\right)$. The equilibrium convenience premia s_t^M and s_t^B, as well as the equilibrium quantity M_t, are given by Equations (11), (12), and (13).

2.2 Model Implications for Empirical Testing

We now outline the implications for empirical testing, guided by the model.

MBS demand λ_t. Our analysis focuses on the distinctive economic channel—the demand for MBS *relative to* Treasury securities λ_t. Intuitively, an increase of λ_t shifts the demand

[16]It follows that the primary mortgage rate paid by borrowers is the risk-free rate r_t, In practice, some housing demand are indeed rigid, like those related to setting up a family, moving to a good school district, and relocation. Importantly, an alternative setup with competitive banks and elastic household mortgage demand 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.

curve of MBS upward so both the convenience premium s_t^M and supply M_t increase.

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

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

Second, the safety of principal balance 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, if 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, and have been in conservatorship with explicit government support since then. Over the last decade, many initiatives have been proposed to privatize GSEs. Therefore, the safety of principal balance of agency MBS is similar to that of Treasury securities in general, but the strength of government backing is subject to uncertainty, which would affect investors' demand for MBS.

Third, agency MBS has played a prominent role in monetary and regulatory policies since the 2007-09 global financial crisis. In particular, as discussed in the Introduction, agency MBS are included as important HQLAs in the LCR requirement of Basel III for bank regulations, receiving a haircut similar to Treasury securities but more favorable than that of most other AAA-rated assets. Such regulatory constraint should affect investors' demand for agency MBS as safe assets.

Safe asset demand λ_t and Treasury supply B_t. We now consider the effects of Treasury supply B_t and the demand for *all* safe assets γ_t, which have been examined in existing studies (Krishnamurthy and Vissing-Jorgensen, 2012; Sunderam, 2014; Nagel, 2016). These effects are not our focus, but spelling them out is helpful for comparison.

Proposition 2. ***[MBS convenience premium and issuance on*** γ_t ***and*** B_t***]***

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

(b). The MBS convenience premium and issuance increase with the 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 lowers MBS convenience premium because the marginal benefit of liquidity holdings decreases ($v''(\cdot) < 0$); the lower convenience premium then induces a drop in MBS issuance, resulting in a crowd-out effect (see Stein (2012) and Krishnamurthy and Vissing-Jorgensen (2015) for similar effects). In contrast, an increase of γ_t raises MBS convenience premium and issuance because it shifts the demand curves for all safe assets upward. Potential drivers of γ_t include flight-to-safety and the "opportunity cost of money" theory of liquidity premium; see Sunderam (2014) and Nagel (2016) for empirical evidence on these drivers for short-term Treasury securities.

Ratio of the MBS and Treasury convenience premia. As shown so far, the convenience premium s_t^M in Eq. (12) depends not only on the MBS-specific demand factor λ_t that we focus on, but also on the demand factor for all safe assets γ_t and the equilibrium quantity of all safe assets Q_t. A "structural" implication of our standard safe asset modeling, as can be seen from (12) and (13), is that the ratio s_t^M/s_t^B can recover λ_t we focus on exactly.

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

Therefore, the ratio of MBS to Treasury convenience premia eliminates both γ_t and Q_t and depends solely on λ_t. The empirical prediction from this implication, which we will bring to the data, is that with confounding effects excluded, the ratio of MBS to Treasury convenience premia should be a better proxy for the MBS-specific safe asset demand than the MBS convenience premium per se.

3 Empirical Analyses

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

3.1 Empirical Measures

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

Measures of convenience premia. Following Krishnamurthy and Vissing-Jorgensen (2012), we use AAA corporate bonds as the benchmark and measure 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 amount of issuance among different coupon stacks, have the average loan rate closest to the prevailing mortgage rate, and are most actively traded (Gao, Schultz, and Song, 2018). The 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 the corporate bonds and MBS using measures of durations and the 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 Treasury convenience premium, denoted as $s^{AAA-Tsy}$.[17]

The first two rows of Table 1 report summary statistics of 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. The top left panel of Figure 2 plots monthly series of AAA-FN30y and AAA-Treasury yield spreads.

Measures of MBS supply. To measure the MBS supply, we use monthly new issuance amount of FN30y MBS. Since MBS supply in our model (M_t) is endogenously determined in equilibrium in response to variation of λ_t spontaneously, new issuance amount, as a "flow" measure, matches M_t better than the outstanding MBS "stock" that includes seasoned MBS driven by past market conditions.

The third row in Panel A of Table 1 reports summary statistics of monthly issuance amount of FN30y MBS (in $billions). The mean monthly issuance is about $18 billion, with

[17] In addition, we consider the yield spread between MBS and Treasury, often known as option-adjusted spread (OAS), which can help differentiate the effects of λ_t from γ_t; see Section B.3.

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	18.31	12.84	1.51	10.88	15.76	21.24	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.

a standard deviation of $13 billion. The top right panel of Figure 2 plots monthly series of FN30y issuance amount. It undergoes an upward trend up to 2001, with an average monthly issuance of $10 billion, and stays stable afterwards around an average monthly issuance of $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 prepayment incentive. We measure the prepayment incentive of FN30y MBS using mortgage rate, which captures the expected moneyness when interest rate drops in the future. Specifically, we obtain the rate on 30-year fixed-rate mortgage loans from the Freddie Mac Primary Mortgage Market Survey (PMMS). Because short-term and long-term interest rates are closely tied with each other, we also obtain federal funds target rate as another measure of interest rates. The bottom panels of Figure 2 plot monthly series of PMMS and federal funds rate, both of which exhibit a downward trend from 1990s to 2015. Yet, there are episodes like early 2000s during which the substantial increase of federal funds rate was only accompanied by modest increase of PMMS.

Convenience premium measures of short-term safe assets. Agency MBS and Treasury bonds are long-term safe assets. For better comparison to the research on short-term

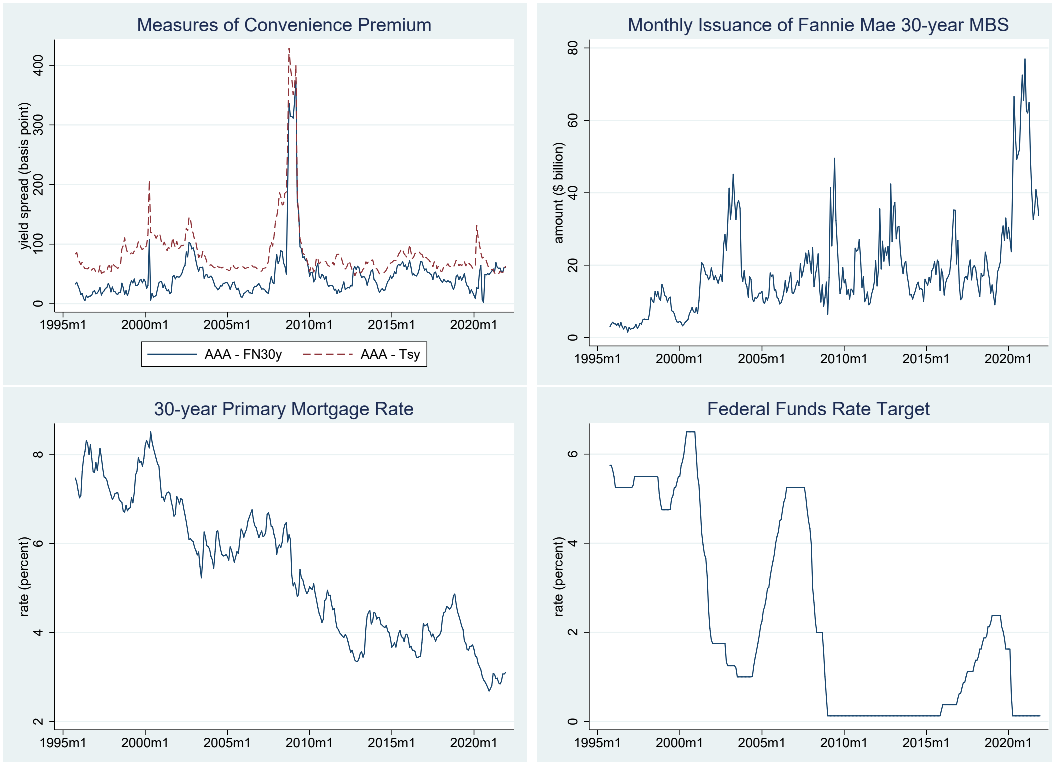

Figure 2: Monthly Series of Empirical Measures

This figure plots monthly time 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 federal funds target rate (bottom right panel). The sample period is October 1995 - December 2021.

safe asset (e.g., Nagel, 2016), we consider MBS repo and Treasury repo as short-term safe assets. We measure their convenience premia using the spread of one-month general collateral (GC) repo rates of MBS and Treasury relative to one-month certificate of deposit (CD) rates. Repo rates are from Bloomberg and available starting from 2004, while CD rates are from the Federal Reserve Economic Data (FRED). Panel B of Table 1 reports summary statistics of the CD-MBS repo spread and CD-Treasury repo spread from January 2004 to December 2021. The mean CD-MBS repo spread is about 3 bps, lower than that of CD-Treasury repo spread about 14 bps.

Treasury supply and other variables. To measure the Treasury supply (B_t in the model), we obtain quarterly series of the outstanding U.S. government debt to GDP ratio from the Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis.

We linearly interpolate the monthly series, and use the logarithm of debt-to-GDP ratio in empirical analysis, similar to Krishnamurthy and Vissing-Jorgensen (2012) and Nagel (2016).[18] 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).

3.2 Prepayment-Driven MBS Demand

In this section, we present our analyses of the prepayment-driven MBS demand λ_t. We first conduct our baseline analysis of how MBS convenience premium and issuance amount depend on mortgage rate. We then examine how the convenience premia of MBS repo as short-term safe assets depend on the level of interest rates for comparison.

3.2.1 Baseline analysis

As set out in Section 2.2, prepayment-driven MBS demand should *negatively* depend on mortgage rate that captures the future prepayment incentive of newly-issued MBS. Hence, MBS convenience premium and issuance amount should depend on mortgage rate negatively (see Proposition 1). Columns (1) - (2) of Table 2 report monthly time series regressions of $s^{AAA-FN30y}$ and issuance amount of FN30y MBS on 30-year mortgage rate, respectively. We compute robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75T^{1/3}$ (such standard errors are used in all regressions unless specified otherwise). Indeed, mortgage rate negatively affects both $s^{AAA-FN30y}$ and issuance amount with high statistical significance.

We then add other variables in the regressions and report the results in columns (3) - (4). In particular, we include Log(Debt/GDP) as a measure of Treasury supply and find that it negatively affects MBS convenience premium and issuance amount significantly, consistent with Proposition 2 (a). This crowding-out effect confirms the substitutability between agency MBS and Treasury securities in satisfying safe asset demand.[19] We also include the VIX and 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 of Moody's Analytics and controls for corporate default risk, while the slope of yield curve

[18] In the model, different from the MBS supply that is endogenous, the Treasury supply is taken exogenous. Accordingly, we measure the Treasury supply using the outstanding balance that captures the effect of a change in investors' total Treasury holdings on the equilibrium demand for MBS.

[19] 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)	(2)	(3)	(4)
	$s^{AAA-FN30y}$	MBS Issuance	$s^{AAA-FN30y}$	MBS Issuance
PMMS	-4.117***	-5.140***	-11.337***	-7.617***
	(-2.816)	(-5.833)	(-4.095)	(-8.511)
Log(Debt/GDP)			-26.016**	-10.479**
			(-2.393)	(-2.392)
VIX			3.254**	0.357**
			(2.466)	(2.222)
Slope			7.874***	-1.183
			(3.027)	(-1.410)
Intercept	69.106***	46.057***	130.955**	95.666***
	(7.489)	(8.201)	(2.565)	(4.770)
N	315	314	315	314
R^2	0.019	0.386	0.453	0.453

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 $0.75T^{1/3}$ are reported in parentheses. The sample period is October 1995 - December 2021. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.

captures the state of business cycles and controls for risk premium. Moreover, VIX can also control for flight-to-safety (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-safey effect; see Proposition 2 (b)), while slope is only significant for the former.

Most importantly, regression coefficients on mortgage rate remain negative and statistically significant even with these three variables included as regressors. The effects of mortgage rate are also economically large. Based on estimates in column (3), a one-standard-deviation increase in mortgage rate (1.55%) decreases the MBS convenience premium by about 18 ($\approx -11.337 \times 1.55$) bps, around 40% of the mean value (as reported in Table 1). Based on estimates in column (4), a one-standard-deviation increase in mortgage rate reduces the monthly issuance amount by about \$12 billion ($\approx -7.617 \times 1.55$), roughly 50% of the mean value.

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

	(1) PMMS	(2) $s^{AAA-FN30y}$	(3) Issuance Amount	(4) $s^{AAA-FN30y}$	(5) Issuance Amount
FFR	0.607***	-6.532***	-3.136***	-8.710***	-6.150***
	(17.331)	(-3.587)	(-5.837)	(-3.027)	(-8.267)
Log(Debt/GDP)				-20.871*	-8.266*
				(-1.873)	(-1.724)
VIX				3.193**	0.317**
				(2.413)	(2.067)
Slope				-0.037	-6.855***
				(-0.009)	(-5.715)
Intercept	4.032***	61.535***	25.353***	84.292*	70.485***
	(28.100)	(6.957)	(10.985)	(1.692)	(3.406)
N	315	315	314	315	314
R^2	0.730	0.096	0.286	0.448	0.442

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 $0.75T^{1/3}$ are reported in parentheses. The sample period is October 1995 - December 2021. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.

3.2.2 Convenience premia, opportunity cost of money, and federal funds rate

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

In the first analysis, we regress $s^{AAA-FN30y}$ and issuance amount on federal funds rate and report the results in columns (2) - (5) of Table 3. We observe that similar to mortgage rate, federal funds rate affects $s^{AAA-FN30y}$ and issuance amount in a significantly *negative* way. That is, the higher the level of short-term interest rates, the lower the MBS convenience premium. This negative comovement is in sharp contrast to the *positive* comovement implied by the theory of the opportunity cost of money—higher short-term interest rates imply higher opportunity costs of holding money and hence higher convenience premia of safe assets (see Proposition 2).

The strong empirical support to the theory of opportunity cost of money is in the literature of short-term safe asset (Sunderam, 2014; Nagel, 2016). Hence, in the second analysis, we analyze how convenience premia of short-term safe assets depend on the level of short-term interest rates. As no short-term agency MBS like T-bills are available, we focus on MBS repo that effectively "transforms" long-term MBS into short-term safe assets. We also consider Treasury repo for comparison. The first two columns of Table 4 report results of regressing the CD-Treasury repo spread on federal funds rate; CD rates correspond to the yield of AAA in the long-term asset case.[20] Consistent with Nagel (2016), the regression coefficients are significantly positive. More importantly, the last two columns show that regression coefficients of the CD-MBS repo spreads on federal funds rate are also significantly *positive*, in stark contrast to the significantly negative dependence of $s^{AAA-MBS}$ on federal funds rate (as reported above in Table 3).

Taken together, MBS convenience premium depends on the level of short-term interest rates *negatively*, which differentiates the effects of the prepayment-driven MBS demand from the effects of the opportunity cost of money.[21] This negative dependence contrasts strikingly with the *positive* dependence of the convenience premium of MBS repo, demonstrating a novel effect of repo contracts in transforming long-term bonds into short-term assets.

The last novel observation has further implications on the underlying drivers of investors' demand for short-term near-money assets, which is a focus in many existing studies (Sunderam, 2014; Nagel, 2016; Carlson et al., 2016; Kacperczyk et al., 2019). In particular, Panel B in Table 1 shows that Treasury repo convenience premium is about 11 bps lower than MBS repo convenience premium, suggesting that investors prefer Treasury collateral in the repo market (see Figure 1 on the more extensive use of Treasury securities as collateral in repo contracts). In other words, at the short end, the mechanism of the opportunity cost of money prevails, and investors seem to concern little about the prepayment risk of the underlying collateral (which hits MBS but not Treasury); this is because haircuts help insulate creditors to lose from low-frequency prepayment risk of the MBS collateral. This finding therefore

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

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

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 $0.75T^{1/3}$ reported in parentheses. The sample period is February 2004 - December 2021. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.

suggest that investors' preference of Treasury collateral over MBS likely comes from either the stronger government backing of Treasuries during rare disaster events (modeled as jump risk), or regulatory constraints.[22]

3.2.3 Unobservable aggregate shocks

One concern about the results on the prepayment-driven MBS demand documented in the previous sections is that some "unobservable" drivers of MBS convenience premia are missing from the time series regressions presented above, which can confound our estimates. Such drivers include unobservable demand shocks for MBS or all safe assets, as well as unobservable MBS supply shocks. In this section, we conduct two sets of analyses to address concerns regarding these drivers.

[22]The liquidity difference between newly-issued MBS and Treasury securities is negligible. For example, Table A.1 reports that the average trading cost of newly-issued agency MBS is about 1.2-1.4 cents per $100 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 par value for on-the-run 10-year Treasury).

Cross-sectional analysis In the first set of analyses, we confirm the effects of mortgage rate using panel data of newly-issued MBS for which we can include time series fixed effects as controls. In particular, different mortgage borrowers can receive diverse mortgage rates because of different loan characteristics (such as loan amount, occupancy, loan purpose like purchase or refinance, and loan-to-value ratio), borrower characteristics (such as credit score, debt-to-income ratio, and employment status), and lender characteristics (such as size, institution type like commercial banks or mortgage financing companies, and pricing model that is used to assess risks). These loans with distinct mortgage rates are usually packaged into MBS with different coupon rates, which are mostly in 50 basis point increments (e.g, 4.5%, 4.0%, 3.5%, etc) and often known as coupon stacks.[23] At any point in time, there are usually two to three coupon stacks in active issuance.

We obtain yields and issuance amounts of the three coupon stacks with the most active issuance activities of Fannie Mae 30-year MBS. Panel A of Table 5 reports summary statistics of these MBS, where issuance rank equal to 1 (3) refers to the coupon stack that has the largest (smallest) issuance amount in each month; coupon stack 1 is actually the production-coupon MBS. Not surprisingly, the moneyness (equal to MBS coupon rate minus current coupon rate) of coupon stack 1 is indeed closest to zero (0.23%) on average. Compared with coupon stack 1, the issuance amounts of the other two are lower but still fairly sizeable, about \$9.50 and \$3.54 billions 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 coupon rate using the sample of these MBS coupon stacks. Time fixed effects are included, so these are equivalent to regressions on moneyness in the cross section. The first two columns of Panel B of Table 5 report results using all three coupon stacks, while the last two columns report results using only the top two MBS coupon stacks. We observe that the coefficients on coupon rate are significantly negative for both $s^{AAA-FN30y}$ and issuance amount. One may worry about the liquidity difference across these coupon stacks; as shown in Table A.1, however, during the period of 2011-2015 for which we have MBS transactions data, trading costs are similar across three coupon stacks (about 1.2-1.4 cents per \$100 par value).[24] Overall, the negative effects of mortgage rate on MBS convenience premium and issuance amount iden-

[23]The MBS coupon represents the amount of interest cash flow an MBS investor will receive every year on the outstanding unpaid principal balance of the underlying mortgage loans. It is also known as pass-through coupon rate.

[24]If anything, coupon stack 1 that has the highest convenience premium has the highest trading cost. Further, it has the lowest the ratio of trading volume to issuance amount or turnover.

Table 5: Cross-Sectional Analysis of 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	0.226	-0.112	0.551	18.310	10.877	21.239	47.24	26.05	56.38
2	0.367	-0.044	0.857	9.497	5.297	11.011	45.57	23.37	51.84
3	0.423	-0.148	1.034	3.538	1.809	4.618	43.50	22.51	52.25

B: Regressions				
	ALL		Issuance Rank≤2	
	$s^{AAA-MBS}$	MBS Issuance	$s^{AAA-MBS}$	MBS Issuance
Coupon rate	-6.674**	-4.021**	-6.509*	-7.213***
	(-2.742)	(-2.907)	(-2.175)	(-5.093)
Intercept	39.956***	3.158***	36.710***	2.678
	(11.300)	(3.750)	(43.104)	(1.324)
N	876	942	584	628
R^2	0.980	0.440	0.990	0.702
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 - January 2020. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.

tified by cross-section data remain highly significant, which helps "rule in" the channel of prepayment-driven MBS demand.[25]

[25] It is worth comparing our cross-sectional analysis with those in several recent papers, including Boyarchenko et al. (2019) and Diep et al. (2021) who study prepayment risk premium and Fusari et al. (2021) who study liquidity premium associated with the unique to-be-announced trading of MBS. Our analysis differs in two ways. First, we consider newly-issued MBS, 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 of newly-issued and seasoned MBS (similar to the difference between on-the-run and off-the-run Treasury securities studied in Duffie (1996), Krishnamurthy (2002), and Vayanos and Weill (2008)). Second, we examine the determinants of MBS issuance amount; the existing papers either do not consider MBS quantity in their analyses (Boyarchenko et al., 2019; Diep et al., 2021) or use issuance amount as a measure for secondary-market liquidity (Fusari et al., 2021).

What unobservable aggregate shocks? In the second set of analyses, we investigate certain specific unobservable aggregate shocks that could confound the prepayment-driven MBS demand shock, and present evidence which help us alleviate these specific concerns.

First, we consider "demand" shocks, either for safe assets in general or specific to MBS (but other than prepayment-driven demand); one such leading candidate is the reduced appetite from foreign investors. In particular, a negative demand shock could cause a *lower* MBS convenience premium, which, if passing on to mortgage borrowers, would lead to a *higher* mortgage rate. The Fed is unlikely to adjust its target rate in response to such shocks. Even if the Fed does, it would cut the federal funds target rates downward to suppress increasing mortgage rate, which is opposite to the strong positive association of the mortgage rate and federal funds target rate in the data; see column (1) of Table 3. Importantly, using federal funds rate as the measure, the results reported in Table 3 show that the effects of interest rates on MBS convenience premium and issuance are still significantly negative.

Second, we consider "supply" shocks to MBS. In particular, household mortgages can vary because of income shocks or mortgage cost movements (like interest expenses and refinancing fees), which naturally lead to variations in the issuance of MBS for which mortgages make up the underlying collateral. One crucial implication of the MBS-supply-driven channel is that MBS convenience premium and issuance should move in opposite directions as higher supply decreases the marginal benefit of MBS holdings ($v''(\cdot) < 0$ in the model). In contrast to this, Table 2 shows that they move in the same direction when mortgage rate varies.[26]

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 announced by the Federal Housing Finance Agency (FHFA) on September 6, 2008, and the second is the progressive implementation of the LCR rule since 2014. 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).

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

[26]In fact, unreported results show that regressing MBS convenience premium on issuance amount directly delivers a positive coefficient, implying that the supply-driven variations are relatively muted in the data.

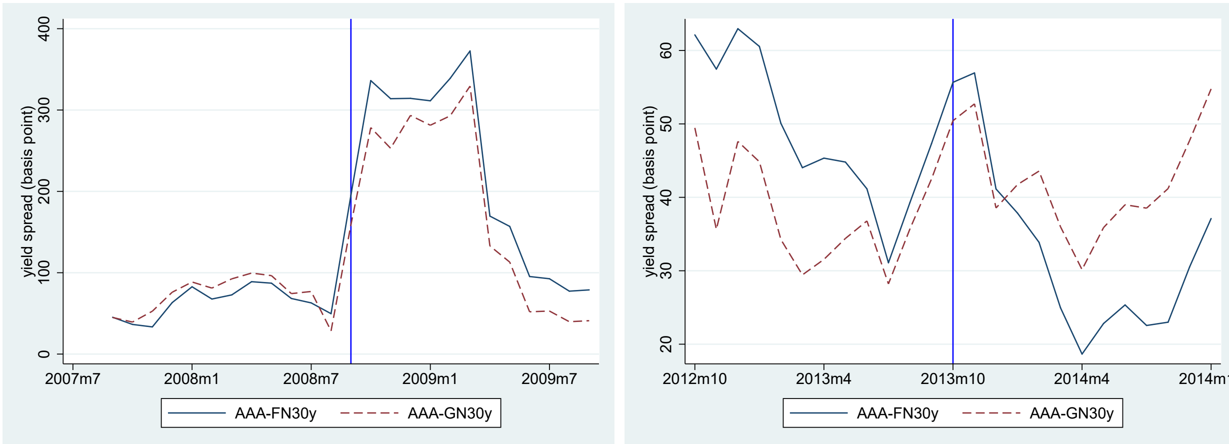

Figure 3: Policy Shocks and Convenience Premium Changes

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 2014 (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.

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

The left panel of Figure 3 plots 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 stayed lower than that of GN30y before the conservatorship but went up above afterwards, based on yields spreads to both AAA corporate bonds and Treasury securities. This pattern is consistent with an increase in demand for Fannie Mae MBS relatively. The moving of FN30y convenience premium above that of GN30y happened shortly before September 2008, likely reflecting market expectations on the Fannie Mae rescue by the U.S. government. The fact that the moving happened before the Fed's MBS purchases announcement on November 25, 2008 also mitigates concerns that the change was 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 started
	Mar	Expansion of the QE1 purchase of agency MBS by an additional $750 billion
2010	Mar	The QE1 purchases of agency MBSs were finished
2011	Sep	The Fed announced to reinvests cash flows from agency MBS into purchases of agency MBS
2013	Jun	The fixed-income market experienced a selloff known as "taper tantrum" since 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 to reform the U.S. MMF industry
	Sep	The U.S. LCR rule was finalized
	Oct	QE3 purchases of agency MBSs ended, 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 of the SEC MMF industry reform
2017	Jan	The LCR requirement was fully phased in
	Apr	The largest globally systemically important banks began public LCR disclosures

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

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

$$s_{it}^{AAA-MBS} = \alpha + \beta_1 \times \text{Post-Policy}_t + \beta_2 \times \text{FN30y}_i + \beta_3 \times \text{Post-Policy}_t \times \text{FN30y}_i + \text{Controls}_t + \varepsilon_{it}, \tag{14}$$

where i = FN30y or GN30y, Post-Policy$_t$ is a dummy for the months after September 2008, and FN30y$_i$ is a dummy for FN30y. The coefficient β_3 captures the change in FN30y convenience premium relative to GN30y. Column (1) in Panel A of Table 7 reports the regression results for the sample of September 2007 – September 2009. We observe that PMMS is significantly negative, consistent with the baseline results in Section 3.2 using the whole sample. Importantly, the estimated coefficient on the interaction term of Post-Policy$_t$ and FN30y$_i$ implies that the FN30y convenience premium increased significantly by about 49 bps relative to GN30y. Column (2) reports the regression results for the shorter window of March 2008 - March 2009 to exclude potential confounding events, and the estimated coefficient remains to be 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 $p < 0.05$, where p is the p-value.

LCR. Turning to the LCR requirement in Basel III, we exploit the difference in the haircut charged to Fannie Mae MBS and to Ginnie Mae MBS as HQLA holdings. The former is 15%, while the latter is zero, equivalent to the haircut assigned to excess reserves at central banks and Treasury securities. (In contrast, the haircut is 50% haircut for investment grade corporate and municipal bonds). This would induce a relative decrease in banks' demand for Fannie Mae MBS compared with Ginnie Mae MBS. The LCR has experienced progressive implementations, and we use October 2013 when the U.S. version of LCR was proposed as the policy even time.

The right panel of Figure 3 plots the yield spreads of FN30y and GN30y against AAA corporate bonds from October 2013 through October 2014. We observe that the FN30y convenience premium mostly stayed above that of GN30y before October 2013 but dropped below afterwards, consistent with a relative decrease in demand for Fannie Mae MBS. The moving of FN30y convenience premium below that of GN30y happened long before the 2016 money market fund reforms, and also after the taper tantrum over March - June 2013 (see Table 6 for major policy events again).

Columns (3) and (4) of Table 7 report results of the regression (14) with Post-Policy$_t$ defined as the dummy for the months after October 2013, for the sample of October 2012 – October 2014 and April 2013 – April 2014, respectively. The estimated coefficients on the interaction term imply that the FN30y convenience premium decreased significantly by about 10-20 bps relative to GN30y.

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

3.4 Ratio of MBS to Treasury Convenience Premia

We have so far focused on how the MBS convenience premium (s_t^M) changes when the MBS-specific safe asset demand λ_t varies. In this section, we examine the more "structural" implication of the model as stated in Proposition 3: the MBS to Treasury ratio in convenience premium (s_t^M/s_t^B) recovers λ_t exactly and does not depend on other driving forces like γ_t or equilibrium quantify 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 on yield spreads directly (see Table 1). We also observe that the ratio is mostly below 50% before the 2008 crisis, but has stayed above 50% since then. In several episodes like the 2008 crisis and around 2014, the $s^{AAA-FN30y}$ to $s^{AAA-Tsy}$ ratio rises above 100%, implying that MBS convenience premium

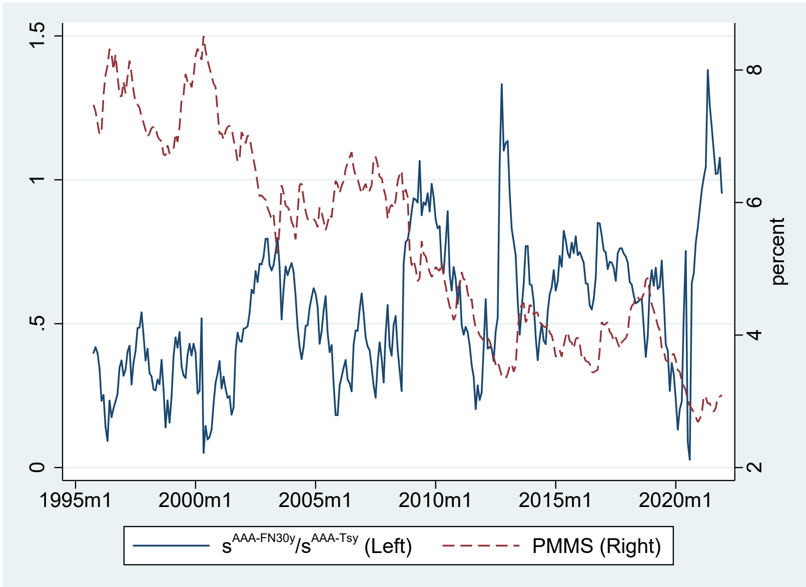

Figure 4: Ratio of AAA–MBS and AAA–Treasury Spreads
This figure plots monthly series of the ratio (left scale) of AAA-FN30y and AAA-Treasury yield spreads, as well as the 30-year mortgage rate PMMS (right scale). The sample period is October 1995 - December 2021.

is even higher than Treasury convenience premium.

One testable implication for this "structural estimation" of MBS-specific demand is that mortgage rate and federal funds rate—as measures of of prepayment-driven MBS demand—should have a higher explanatory power for the ratio than for $s^{AAA-FN30y}$ currently used in Tables 2 and 3. In the first two columns of Panel A in Table 8, we regress $\hat{\lambda}_t$ on mortgage rate and federal funds rate, respectively. We observe that the regression coefficients are significantly negative, consistent with the baseline analysis in Section 3. Importantly, the regression R^2 is 35.7% using mortgage rate and 42.3% using federal funds rate, substantially higher than those for $s^{AAA-FN30y}$ that equal 1.9% and 9.6% respectively, as reported in the last two columns (which we reproduce from Tables 2 and 3 for ease of comparison). The third and fourth columns of Panel A in Table 8 report regression results adding Log(Debt/GDP), VIX, and slope of the yield curve as regressors. These additional variables bring in quite limited improvements in R^2, and are mostly insignificant— especially for the regression using federal funds rate; interestingly, this is consistent with the premise 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

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***	
	(-6.427)		(-5.949)		(-2.816)	
Federal Funds Rate		-0.073***		-0.065***		-6.532***
		(-8.379)		(-3.755)		(-3.587)
Log(Debt/GDP)			-0.069	0.039		
			(-0.972)	(0.457)		
VIX			0.001	-0.000		
			(0.183)	(-0.052)		
Slope			0.067***	0.012		
			(3.976)	(0.389)		
Intercept	1.056***	0.710***	1.253***	0.521	69.106***	61.535***
	(11.246)	(19.472)	(3.543)	(1.325)	(7.489)	(6.957)
N	315	315	315	315	315	315
R^2	0.357	0.423	0.470	0.424	0.019	0.096

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

The first two columns in Panel A report results of monthly regressions of $\hat{\lambda}_t = s_t^{AAA-FN30y}/s_t^{AAA-Tsy}$ on the 30-year mortgage rate (PMMS) and federal funds rate, respectively. The third and fourth columns add 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 Tables 2 and 3 for comparison. Robust t-statistics based on Newey and West (1987) standard errors with the rule-of-thumb bandwidth choice $0.75T^{1/3}$ are reported in parentheses. The sample period is October 1995 - December 2021. Panel B reports the difference-in-difference regressions for the conservatorship and LCR similar to those in Table 7 but using $\hat{\lambda}_t$ instead of $s_t^{AAA-FN30y}$, with robust t-statistics reported in parentheses. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.

using the $s^{AAA-FN30y}$ to $s^{AAA-Tsy}$ ratio. Specifically, the first two columns in Panel B of Table 8 report results of the difference-in-difference regression in (14) 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 is similar for the conservatorship but notably higher for the LCR. One noteworthy observation is that, for the one-year window, effects of the conservatorship and LCR are of similar economic magnitude, around 15% to 18%. This adds further understanding on top of the 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 to the widely-used "structural" framework of safe asset convenience premium. Further, by recovering the MBS-specific safe asset demand, this market-based indicator can be used to examine the economic drivers directly. For instance, because the adjustment for the value of prepayment options is done based on statistical prepayment models, the MBS yield measure we use contains a prepayment-risk-premium component. However, as shown by Boyarchenko et al. (2019), this component contributes very little to the time series variations we focus on. In fact, if our results were mainly driven by the prepayment-risk-premium channel, then one would expect a strong *negative* dependence of $\hat{\lambda}_t$ on prepayment risk premium. In contrast, for the sample period of 1995-2010, we find a *positive* correlation (34%) between the prepayment-risk-premium measure calculated by Boyarchenko et al. (2019) and $\hat{\lambda}_t$. Although far from conclusive, this result does point to the significant roles played by economic mechanisms beyond prepayment risk premium, such as prepayment modeling uncertainty (Hansen and Sargent, 2001), information asymmetry (Gorton and Pennacchi, 1990), or coordination issues emanated from the these two forces (He et al., 2019). We leave the important issue of separating convenience premium from risk premium, which is a challenging task for the safe-asset literature, for future research.

3.5 Robustness

In this section, we briefly summarize a number of additional analyses and robustness conducted (see Appendix B for details).

First, as mentioned earlier in Section 3.2.3, Table A.1 presents summary statistics for the cross section of newly-issued MBS using the data of MBS transactions from 2011 to 2015. We observe from Panel A of Table A.1 that the moneyness, issuance amount, and AAA-MBS yield spread are very similar to those reported in Panel A of Table 5 for the full sample of 1995 to 2021, showing that this 2011-2015 sample is quite representative. Importantly, the liquidity metrics reported in Panel B of Table A.1 show that there is no difference in secondary market liquidity across the three newly-issued coupon stacks we use; if anything, the highest-issuance coupon stack is less liquid.

Second, in addition to the Fannie Mae 30-year MBS used in our baseline analyses, we consider 15-year MBS and MBS issued by Freddie Mac and Ginnie Mae. As reported in Table A.2, the convenience premia of these alternative MBS are of similar magnitudes on average to those of Fannie-Mae 30-year MBS, and our main results remain robust using the yields of these MBS.

Third, we show that the effect of mortgage rate remains negative and highly significant even after controlling for the duration differential between AAA corporate bonds and agency MBS; see Table A.3. In fact, the duration differential does not significantly affect our duration-mismatch-adjusted measure $s^{AAA-FN30y}$, suggesting that our particular duration adjustment procedure works reasonably well.

Fourth, in addition to following Krishnamurthy and Vissing-Jorgensen (2012) to use the VIX and slope of the yield curve as controls for variations of the AAA-MBS yield spread that are specific to corporate default risk, we 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 little changed using these measures; see Table A.3.

Fifth, as mentioned 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 yield measures of Fannie-Mae 30-year MBS from an alternative major Wall Street dealer and confirm the negative effect of mortgage rate on the AAA-MBS yield spread; see Table A.3.

Sixth, related to demand shocks discussed in Section 3.2.3 but working in a slightly different way, one particular concern on using mortgage rate to proxy for MBS-specific safe asset demand is on business cycle and its associated flight-to-safety effect. In particular, mortgage rate is usually *lower* in economic downturns (see Figure 2), during which fight-to-safety is stronger, which can lead to a *higher* convenience premium. As shown in Proposition A.1, if lower mortgage rates proxy for greater flight-to-safety (γ_t in the model), it should *positively* affect Treasury-MBS yield spread $s^{Tsy-FN30y}$ (as γ_t negatively affects this spread). This is opposite to the significantly *negative* coefficients when we regress $s^{Tsy-FN30y}$ on mortgage rate, as shown in the last two columns of Table A.3.

Seventh, because yield spreads, interest rates, and supply quantities are persistent over time, one may concern that regressions using the level series may generate certain spurious correlations. As shown in Table A.4 which reports regression results using monthly changes, mortgage rate remains highly significant and negatively affects MBS convenience premium, while no variables can explain MBS issuance amount significantly and economically. This suggests that MBS issuance amount is mainly driven by persistent economic forces while MBS convenience premium comprises both permanent and transitory components.

Finally, the effects of mortgage rate remain significantly negative both for the sample excluding the 2008 crisis period and for the sample excluding the post-2020 COVID-crisis period; see Table A.4.

4 Conclusion

We conduct the first analysis on the economic role of agency MBS as safe assets. Our estimates show that the average MBS convenience premium is about half of that of Treasury bonds. We further document the important effects of 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 policies, 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 are important for polices on housing finance. The significant effects of mortgage rate and federal funds rate on the MBS demand 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 Details of Model Implications

In this appendix, we provide detailed proofs for propositions in Section 2.2, as well as an additional model implication.

Proof. of Proposition 1. Because $\kappa''(\cdot) > 0$, we have $\phi'(\cdot) > 0$. Taking derivatives of both sides of (12) 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 equilibrium quantity, by Equation (11), we have

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

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

□

Proof. of Proposition 2. Taking derivatives of both sides of (12) 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, we have

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

because $\phi' > 0$ and $ds_t^M/dB_t < 0$.

Then taking derivatives of both sides of (12) 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 equilibrium quantity, by Equation (11), we have

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

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

□

In addition, we consider the difference between MBS and Treasury convenience premia, which is helpful to differentiate the effects of λ_t from those of γ_t.

Proposition A.1. ***[Difference between MBS and Treasury convenience premia]*** *The difference between MBS and Treasury convenience premium $s_t^M - s_t^B$ is equal to the Treasury-MBS yield spread $r_t^B - r_t^M$, which increases with λ_t but decreases with γ_t: $d(s_t^M - s_t^B)/d\lambda_t > 0$, and $d(s_t^M - s_t^B)/d\gamma_t < 0$.*

Proof. of Proposition A.1. First, we have

$$ds_t^B/d\lambda_t = \gamma_t v''(\cdot)(\lambda_t \phi' ds_t^M/d\lambda_t + \phi) < 0$$

because $v''(\cdot) < 0, \phi' > 0$, and $ds_t^M/d\lambda_t > 0$ (as shown in Proposition 1). In consequence, $d(s_t^M - s_t^B)/d\lambda_t > 0$. Moreover,

$$\begin{aligned} ds_t^M/d\gamma_t - ds_t^B/d\gamma_t &= \frac{\lambda_t v'}{1 - \lambda_t^2 \gamma_t v'' \phi'} - \frac{v'}{1 - \lambda_t^2 \gamma_t v'' \phi'} \\ &= \frac{(\lambda_t - 1) v'}{1 - \lambda_t^2 \gamma_t v'' \phi'} < 0, \end{aligned}$$

because $\lambda_t < 1$, $v''(\cdot) < 0$, $\phi' > 0$, and $v' > 0$.

□

The positive dependence of $s_t^M - s_t^B$ on λ_t is straightforward: an increase of λ_t implies an increase in the demand for MBS relative to Treasury, so the difference of their convenience premium should increase. The negative dependence of $s_t^M - s_t^B$ on γ_t is also intuitive: an increase of γ_t implies an increase in the demand for all safe assets; given that MBS provides lower convenience benefit than Treasury ($\lambda_t < 1$), the increase in its convenience premium is lower for Treasury convenience premium. These two implications can help differentiate λ_t and γ_t as their effects are opposite in signs.

B Additional Results and Robustness Checks

We provide a number of additional results and robustness checks.

B.1 Secondary Market Liquidity

Table A.1 presents summary statistics on the 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 the so-called to-be-announced (TBA) forward contract, which accounts 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 4% coupon rate), corresponding to the coupon stack we consider in the main analyses.

Panel A of Table A.1 reports summary statistics of the moneyness, issuance amount, and AAA-MBS yield spread for the three coupon stacks with the most active issuance activities of Fannie Mae 30-year MBS 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 sample from 1995 to 2021. Hence, this 2011-2015 sample is quite representative for the cross section of newly issued MBS.

Importantly, Panel B of Table A.1 reports summary statistics of 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 of similar magnitudes, all in the tight range of 1.2-1.4 bps. The average trading volume decreases from $316 billion for coupon stack 1 with the highest issuance amount to $116 billion for coupon stack 3 with 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 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 in the paper focus on Fannie Mae 30-year MBS that comprise the largest fraction of agency MBS. In this section, we conduct robustness checks using Freddie Mac and Ginnie Mae MBS and 15-year MBS.

In particular, the first three columns in Panel A of Table A.2 report results of 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 mortgage rate as well as Log(Deb/GDP), VIX, and slope of term structure. The last three columns report the regression results for the respective monthly issuance amounts. We observe that the regression coefficients are all negative and significant, similar to the baseline results using FN30y.

In addition, there are some differences in convenience premium of these different 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 feature an implicit government backing before the conservatorship in 2008 and have been supported by the U.S. Treasury since then. Moreover, short tenor can mitigate the effect of prepayment, so 15-year MBS should be less subject to prepayment uncertainty than 30-year MBS. These effects imply that the convenience premium of FH30y should be similar to that of FN30y while convenience premia of GN30y and FN15y should be higher. However, 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. Panel B of Table A.2 reports summary statistics of the yield spreads of FH30y, GN30y, and FN15y relative to FN30y, which are equal to the convenience premium of FN30y minus those of FH30y, GN30y, and FN15y. We observe that the average differences are all positive, but quantitatively tiny, up to only 5 bps. That is, the convenience premia of these different MBS are of similar magnitudes on average.

B.3 MBS Yield Spreads

In this section, we present four additional results and robustness checks on 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 the FN30y MBS and AAA corporate bonds (see Appendix Appendix C for details). To confirm the robustness of our main results to the duration mismatch, the first column of Table A.3 includes duration differential $DUR^{AAA-FN30y}$ in the regression of $s^{AAA-FN30y}$ as a control variable. Further, the second column reports the regression result 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 insignificant for the duration-mismatch-adjusted spread, suggesting that our duration adjustment works reasonably well. Importantly, the effect of mortgage rate remains negative and highly significant for both spread measures controlling for duration differential.

Second, the yields of both AAA corporate bonds and FN30y MBS used to compute the baseline measure $s^{AAA-FN30y}$ contain a credit risk component. The former is about the default of the bond-issuing firms, while the later is about 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.

The third column of Table A.3 reports the results of regressing the credit-risk-adjusted $s^{AAA-FN30y}$ on mortgage rate. We observe that the regression coefficient on mortgage rate remains significantly negative, consistent with the baseline analysis. Furthermore, the fourth and fifth columns report the results of the difference-in-difference regression in Eq. (14) for the conservatorship and LCR, using the short windows similar to those in 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 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 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. The last column of Table A.3 reports the results of regressing the alternative measure of $s^{AAA-FN30y}$ on mortgage rate. The regression coefficients on mortgage rate are significantly negative, similar to the baseline results.

Finally, we consider the yield spread of MBS against Treasury securities rather than against AAA corporate bonds in the baseline analyses. In particular, the last two columns of Table A.3 report results of regressing the Treasury-MBS yield spread $s^{Tsy-FN30y}$ of Fannie Mae 30-year MBS on the mortgage rate, as well as control variables. We observe that the regression coefficients are significantly negative, consistent with Proposition A.1. A side benefit of considering both AAA-MBS and Treasury-MBS yield spreads is that the significant effects of mortgage rate on both alleviate concerns on yield variations specific to either AAA corporate bonds or Treasury securities.

B.4 First-Differenced Regressions and Subsamples

In this section, we conduct two robustness checks on the data sample.

First, the measures of yield spreads, interest rates, and supply quantities are quite persistent and regressions using the level series may generate some spurious correlations. To help address this concern, we consider regressions using monthly changes. The first two columns of Table A.4 report the results of time-differenced regressions for AAA-MBS yield spreads. We observe that VIX remains significant but Log(Debt/GDP) and slope lose their significance compared with level regressions as reported in Table 2. Importantly, mortgage rate remains highly significant and negatively affects MBS convenience premium. In contrast, from the third and fourth columns of Table A.4, all variables but VIX are insignificant in affecting MBS issuance amount in time-differenced regressions, and the sign of the regression coefficient on VIX is opposite to that in level regressions. This pattern suggests that MBS issuance amount is mainly driven by persistent economic forces while MBS convenience premium comprises both permanent and transitory components.

Second, as shown in Figure 2, convenience premium measures experience extremely large variations in the 2008 crisis, with AAA-MBS yield spread reaching almost 400 bps. Moreover, the MBS issuance experiences large variations after the COVID-19 crisis in 2020. To make sure that our results are not driven by these crisis sample periods exclusively, the last four columns of Table A.4 report regression results for the sample excluding the 2008 crisis period, defined as December 2007 - June 2009 following the NBER definition of business cycles, and for the sample excluding the period since 2020. The regression coefficients on mortgage rate are still significantly negative, similar to the baseline results.

C Details of Data and Measures

In this section, we provide details on 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 the so-called level 1 assets with zero haircut). The estimates of Treasury securities have a potential upward bias because they may include Ginnie Mae securities and foreign sovereign bonds, whereas the estimates of agency MBS have both a potential upward bias from including agency debt and a potential downward bias from missing Ginnie Mae MBS. For 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 much larger than our estimate (10%).

Repo outstanding balance. The outstanding balances of tri-party repo reported in Figure 1 are obtained from the Federal Reserve Bank of New York.[27] 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 a sum of the "Agency MBS" and "Agency CMOs". The amount of other collateral is a sum of the "ABS Investment Grade", "CMO Private Label Investment Grade", "Corporates Investment Grade", "Money Market", and "Municipality Debt".

Measures of convenience premia. The agency MBS yields, of 30-year production-coupon MBS guaranteed by Fannie Mae (FN30y), Freddie Mac (FH30y), and Ginnie Mae (GN30y) and of 15-year production-coupon MBS guaranteed by Fannie Mae (FN15y), are 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

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

also 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 respectively 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 of AAA corporate bonds to duration-matched Treasury and the negative of the OAS of agency MBS to Treasury, both directly from the Bloomberg Barclays index series, are used as $s^{AAA-Tsy}$ and $s^{MBS-Tsy}$, respectively. In addition, adjustment for default, we obtain CDS spreads on Fannie Mae and NAIG from Markit.

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

Supply variables. The monthly new issuance amount of 30-year production-coupon Fannie Mae MBS is obtained from disclosure reports of Fannie Mae, historically collected by eMBS. Data on the outstanding U.S. government debt to GDP ratio is from the FRED, specifically, the seasonally adjusted quarterly series of the "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 from the U.S. Office of Management and Budget. Similar to Nagel (2016), We linearly interpolate the quarterly series to obtain monthly measures.

Time series factors. The mortgage rate series are from the Freddie Mac primary mortgage market survey (PMMS) on fixed-rate mortgage loans. They are available at the weekly frequency and the monthly measure is constructed as the average of weekly observations over a month. The series of federal funds target rate are from the FRED, with point target rate prior to December 16, 2008 and target range afterwards for which the mid-point is used. The VIX series are 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 3-month T-bill rate.

Cross section of newly-issued MBS. We obtain the coupon-stack-level series of yields of 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 we rank all coupon stacks by their issuance amounts and keep the top three coupon stacks. We obtain the current-coupon rate−the par coupon rate of 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 of MBS transactions and liquidity measures. We use the MBS transaction data from the Financial Industry Regulatory Authority (FINRA) through its Trade Reporting and Compliance Engine (TRACE) that became available after May 2011 (our access to the data is through July 2015). Each trade record contains the trade type, agency, loan terms, security coupon rate, price, par value, trade date, and 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 keep the outright TBA transactions of Fannie Mae 30-year MBS 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 the 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 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 day; otherwise, we exclude the standard-alone transactions.

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 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						
	$s^{AAA-MBS}$			Issuance Amount		
	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. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.

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

	Duration Adjustment		Credit-risk-adjusted			Alternative	$s^{Tsy-FN30y}$	
	$s^{AAA-FN30y}$	Unadjusted spread	$s^{AAA-FN30y}$			Dealer		
PMMS	-11.910***	-17.311***	-21.390*	-81.33***	-166.70***	-8.933***	-9.195***	-6.311***
	(-4.764)	(-5.613)	(-1.956)	(-8.32)	(-3.96)	(-3.612)	(1.601)	(-2.733)
$DUR^{AAA-FN30y}$	1.516	11.340***						
	(0.677)	(4.550)						
Log(Debt/GDP)	-31.773**	-60.296***	-100.075***	94.16	-181.36	12.698		7.927
	(-2.427)	(-3.832)	(-3.578)	(1.40)	(-1.09)	(0.555)		(0.854)
VIX	3.244**	3.513***	4.710***	2.41***	3.56***	3.695***		-1.132***
	(2.431)	(2.876)	(7.088)	(3.29)	(3.26)	(2.927)		(-5.102)
Slope	8.854***	21.055***	-0.211	37.16*	156.50***	2.136		5.957***
	(3.232)	(6.742)	(-0.082)	(1.67)	(4.20)	(1.022)		(3.634)
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	12.385	-22.113
	(2.465)	(3.654)	(2.517)	(0.35)	(1.45)	(0.761)	(8.635)	(-0.461)
N	315	315	123	26	25	242	315	315
R^2	0.455	0.583	0.740	0.98	0.91	0.504	0.328	0.481

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, while the last two columns report regression results for Treasury-FN30y yield spreds. 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 $0.75T^{1/3}$ are reported in parentheses. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.

Table A.4: First-Differenced Regressions and Subsamples

	Monthly Changes				Exclude the 2008 Crisis		Exclude Post-2020	
	$\Delta s^{AAA-FN30y}$	$\Delta s^{AAA-FN30y}$	$\Delta Issuance$	$\Delta Issuance$	$\Delta s^{AAA-FN30y}$	$\Delta Issuance$		
ΔPMMS	-19.729**	-32.242**	0.856	0.372	-7.604***	-7.826***	-7.974***	-6.622***
	(-1.994)	(-2.340)	(0.498)	(0.186)	(-4.632)	(-8.169)	(-4.693)	(-8.872)
ΔLog(Debt/GDP)		-65.256		42.474	-15.288**	-10.971**	-14.438**	-17.142***
		(-0.480)		(1.161)	(-2.020)	(-2.531)	(-2.045)	(-4.418)
ΔVIX		1.546***		-0.170**	0.580*	0.530***	0.846*	0.161
		(2.700)		(-2.049)	(1.727)	(2.917)	(1.911)	(1.353)
ΔSlope		14.422		1.159	5.093***	-1.234	4.250***	0.189
		(1.492)		(0.829)	(3.877)	(-1.595)	(3.452)	(0.348)
Intercept	-0.217	-0.325	0.110	0.013	120.431***	95.550***	115.748***	116.063***
	(-0.198)	(-0.372)	(0.360)	(0.046)	(3.401)	(4.783)	(3.547)	(6.092)
N	315	315	314	314	296	295	272	272
R^2	0.028	0.169	0.001	0.025	0.348	0.493	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 $0.75T^{1/3}$ are reported in parentheses. Significance levels: ** for $p < 0.01$ and * for $p < 0.05$, where p is the p-value.