Defragmenting Markets: Evidence from Agency MBS *

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Abstract

Agency MBS issued by Fannie Mae and Freddie Mac have historically traded in separate forward markets. We study the consequences of this fragmentation, showing that market liquidity was concentrated in Fannie Mae MBS, reflected in higher trading volume, lower trading costs, a liquidity premium, higher issuance, and higher guarantee fees compared to Freddie Mac. We then analyze a change in market design – the Single Security Initiative – which consolidated the two forward markets in June 2019. Consistent with network externality theories of liquidity, consolidation increased Freddie Mac MBS liquidity together with some improvement for Fannie Mae; this was in part achieved by aligning fundamentals of the MBS issued by these two agencies, mitigating adverse effects of asset heterogeneity.

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I Introduction

Fragmentation is a pervasive feature of financial markets. For example, stock trading is fragmented into various exchanges, electronic communication networks, and alternative trading systems. Fragmentation is even greater for fixed-income securities traded bilaterally over-the-counter with dealers (e.g., Treasuries, mortgage-backed securities, corporate bonds, and interest rate and credit derivatives). Theory shows that fragmentation can reduce liquidity due to the loss of liquidity network externalities (Mendelson, 1987; Pagano, 1989; Chowdhry and Nanda, 1991), but conversely may improve market quality by fostering competition across trading venues (Economides, 1996). Many empirical studies analyze the effects of fragmentation but focus on equity markets almost exclusively.

In this paper, we study market fragmentation in one of the largest fixed-income markets in the world, the agency mortgage backed securities (MBS) market dominated by the government sponsored enterprises (GSEs) Fannie Mae and Freddie Mac.[1] Agency MBS trading is concentrated in the "To-Be-Announced" (TBA) forward market, in which any MBS within a cohort can be delivered at settlement, similar to Treasury futures (Gao, Schultz, and Song, 2017; Vickery and Wright, 2011). Until recently, MBS issued by the two GSEs traded in separate TBA market segments and were not fungible with one another.

We study the liquidity effects of this fragmentation, and then analyze a landmark shift in market structure — the Single Security Initiative — which consolidated Fannie Mae and Freddie Mac MBS trading into a single forward market in June 2019. Three distinctive features of our analysis shed new light on theories of endogenous market fragmentation and liquidity; we (1) analyze not only secondary market trading but also primary market issuance and issuer fee income, (2) study an unusual large-scale market design experiment that significantly altered the degree of fragmentation, and (3) consider the effect of asset

[1]$9.3 trillion of agency MBS was outstanding as of 2021:Q4 (source: Securities Industry and Financial Markets Association, SIFMA), smaller than the $22.6 trillion of Treasury securities but comparable to $10.1 trillion of corporate bonds and significantly higher than $4.1 and $1.6 trillion of municipal bonds and asset-backed securities outstanding respectively. Around 90% of agency MBS is backed by 1-4 family residential mortgages; the remainder comprises multifamily and other commercial mortgages (see Fuster, Lucca, and Vickery 2021 for a more detailed breakdown.)

heterogeneity, which is a key feature of fixed-income markets and distinguishes our analysis from existing studies that focus on homogeneous assets (Bessembinder, Spatt, and Venkataraman, 2019).

In the first part of the paper, we show that both secondary market trading and primary market issuance were historically highly concentrated in the Fannie Mae TBA segment. This is consistent with theories of endogenous market concentration, which predict market activity will concentrate in a single venue due to network externalities, often summarized as "liquidity begets liquidity" (e.g., Pagano, 1989; Vayanos and Weill, 2008). These theories, which typically consider assets that are ex-ante identical, are silent as to which segment will be focal. But if one segment has even a slight ex-ante advantage, liquidity network externalities would amplify the advantage and likely cause this segment to become dominant. In our case, Fannie Mae's liquidity dominance likely reflects that it is older and historically larger than Freddie Mac (see Appendix A).

We use four measures to quantify the concentration in the secondary market TBA trading: trading volume scaled by outstanding balance, round-trip trading cost, prices, and yields.[2] Agency MBS are typically issued with coupons in 50 basis point (bp) increments, and TBA trading occurs at a coupon-cohort level (e.g., Fannie Mae 30-year MBS with a 4% coupon). Consequently we also conduct most of our analysis at the cohort level.

We show that Fannie Mae TBA trading volume was 7-10 times higher than Freddie Mac on average prior to market consolidation (specifically, up to July 2016 when the design and a firm timetable for the Single Security Initiative were set).[3] Trading costs were also lower for Fannie Mae, by about half, although the difference was relatively small in absolute terms given that the TBA market overall is extremely liquid (our estimate of

[2]Calculated as the difference between dealers' selling prices to and buying prices from customers, round-trip cost is a standard measure used in studies of over-the-counter trading (Bessembinder, Maxwell, and Venkataraman, 2013; Friewald, Jankowitsch, and Subrahmanyam, 2017; Gao, Schultz, and Song, 2017). Moreover, similar to Gabaix, Krishnamurthy, and Vigneron (2007), Boyarchenko, Fuster, and Lucca (2019), and Song and Zhu (2019), the yield spread measure we use is the option-adjusted spread (OAS), an estimate of MBS excess returns after accounting for the prepayment option based on a prepayment model.

[3]The trading volume and trading cost samples start in May 2011 when the Financial Industry Regulatory Authority (FINRA) began to collect agency MBS transaction data through its Trade Reporting and Compliance Engine (TRACE). TBA prices and yields are obtained from J.P. Morgan and start in January 1998.

Freddie Mac TBA trading cost is only 2 basis points (bp), consistent with Bessembinder, Maxwell, and Venkataraman (2013) and Gao, Schultz, and Song (2017)). Further, Fannie Mae MBS commanded a liquidity premium over Freddie Mac, of about 25 cents per $100 face value in price and about 5 bp in yield. These estimates control for prepayment speed differences, indicating they are due to liquidity effects rather than differences in prepayment characteristics; as further evidence, we find an economically and statistically significant price and yield difference for TBA coupons trading near par, where prepayment risk premia are negligible (Boyarchenko, Fuster, and Lucca, 2019).

We then quantify how this fragmentation and liquidity pooling affected the MBS primary market. First, we show that Fannie Mae MBS issuance was about 50% higher than Freddie Mac in the years prior to the Single Security Initiative. Second, using data from 10-Q filings we show that Freddie Mac's guarantee fees scaled by loan balance were consistently 5-10 bp lower than Fannie Mae, a gap which remains even after accounting for credit risk differences between the two agencies. This finding is consistent with Freddie Mac's known practice of discounting guarantee fees to compensate sellers for illiquidity and remain competitive with Fannie Mae. In the economic framework of endogenous market concentration and liquidity, this deficit in Freddie Mac's guarantee fee income, which in dollar terms amounted to at least $750 million per year, represents the cost of the loss of liquidity network externalities. This cost was ultimately borne by taxpayers given the government backing of the GSEs, which was implicit before 2008 but became more explicit after they were placed into public conservatorship.

In the second half of the paper, we study the economic effects of the Single Security Initiative, which consolidated Fannie Mae and Freddie Mac trading into a single "Uniform MBS" (UMBS) TBA market in June 2019. Since that time, an MBS seller can deliver MBS issued by either agency, or a combination, when a TBA contract is settled. The Single Security Initiative also standardized MBS design across the two GSEs, to minimize the risk of enlarging asset heterogeneity within each TBA cohort.

We first examine whether market consolidation led to a convergence in liquidity between Fannie Mae and Freddie Mac. By construction, gaps in TBA trading volume, trading cost, and prices entirely disappeared after UMBS implementation. However, liquidity may start to adjust on a forward-looking basis in anticipation of future market consolidation (Amihud and Mendelson, 1986; Huang, 2003; Vayanos, 1998). Accordingly, we study the transition period from July 2016 to March 2019, when UMBS forward trading began. We find that the Fannie Mae-Freddie Mac liquidity gap diminished in this transition period: the trading volume gap shrank by up to 20% while the gap in prices and OAS essentially completely disappeared prior to UMBS implementation. We find no change in the trading cost gap, however. The more complete price and yield convergence suggests that prices adjusted in anticipation of *future* liquidity.

Further, the effects of market defragmentation flowed through directly to the primary market. After the implementation of UMBS, the gap in MBS issuance between Fannie Mae and Freddie Mac has shrunk significantly, and the difference in guarantee fees between the two GSEs has entirely disappeared as Freddie Mac has been able to discontinue the practice of discounting its fees.

A network externality view of liquidity would predict that consolidation would lead not just to convergence between Fannie Mae and Freddie Mac, but also an *absolute* improvement in liquidity for both GSEs. However, there was also a risk of unintended adverse consequences. TBAs trade on a cheapest-to-deliver basis; as a consequence, higher-value MBS trade individually in the less liquid specified pool market. Consolidating the Fannie Mae and Freddie Mac TBA segments could enlarge asset heterogeneity within each TBA cohort, diverting more trade to the specified pool market and diminishing overall market liquidity (Li and Song, 2020).

Aware of these risks, regulators took several steps to align MBS characteristics between the two GSEs, such as creating a common securitization platform for UMBS issuance, harmonizing the design of MBS issued by the two agencies, and setting and monitoring limits on prepayment speed differences between Fannie Mae and Freddie Mac. We present three forms of evidence that these steps successfully preserved homogeneity within UMBS

TBA cohorts. First, the difference in realized prepayment speeds between Fannie Mae and Freddie Mac MBS declined as UMBS implementation approached, remained below 1 percentage point over 2014-2019, and stayed low after UMBS implementation despite a refinancing wave. Second, using data on the Federal Reserve's TBA settlements, we show that Fannie Mae and Freddie Mac UMBS are almost equally likely to be delivered as "cheapest-to-deliver" MBS pools to settle TBA trades. Third, we find that the UMBS implementation does not result in migration of Fannie Mae MBS trading to the SP market relative to Freddie Mac MBS. Given that homogeneity was preserved, Fannie Mae TBA liquidity should also improve as a result of UMBS, at least to some extent, due to the network externalities associated with TBA market consolidation. We indeed find suggestive supportive evidence of such an effect using Ginnie Mae, which was not part of the Single Security Initiative, as a comparison group — for example Fannie Mae trading volume and issuance increased relative to Ginnie Mae during UMBS transition.

We note that our results pertaining to the UMBS transition should be treated with some caution, because we study a relatively long time window (about 4 years) in which other forces likely affected MBS liquidity and because Ginnie Mae MBS are not an ideal control group (since e.g., they have an explicit, rather than implicit, government guarantee and are backed by loans with different characteristics to GSE pools). However, the Single Security Initiative is the predominant MBS market reform during this period, so using a long time window likely helps to average out other market fluctuations and capture the long-run effects of this reform. Further, one of the most important confounding events—the introduction of the liquidity coverage ratio—favors Ginnie Mae MBS in relative terms, thus our estimates using Ginnie Mae MBS as a control group may be conservative (Roberts, Sarkar, and Shachar, 2018; Gete and Reher, 2020; He and Song, 2020). At the very least, our results provide no indication that UMBS led to a deterioration in Fannie Mae liquidity, while it clearly improved liquidity for Freddie Mac.

Related literature. This paper primarily contributes to the empirical literature on financial market fragmentation. Studies of fragmentation typically focus on the equity market, including Battalio (1997), Amihud, Lauterbach, and Mendelson (2003), Boehmer and Boehmer (2003), Barclay and Hendershott (2004), Hendershott and Jones (2005), Bennett and Wei (2006), Foucault and Menkveld (2008), Barclay, Hendershott, and Jones (2008), and O'Hara and Ye (2011).[4] We instead provide one of the first analyses of market fragmentation in fixed-income markets — a setting where fragmentation is arguably magnified because trading is bilateral and decentralized.

We contribute to the economic understanding of market fragmentation in several ways. First, we trace through the effects of fragmentation not just on secondary market trading but also security issuance and fee income in the primary market.[5] These primary market effects of fragmentation have not been previously analyzed, to the best of our knowledge. Second, we analyze the role of asset heterogeneity, which is a key feature of fixed-income markets and a distinct economic channel from the usual focus on homogeneous assets traded at different venues (Bessembinder, Spatt, and Venkataraman, 2019). Our empirical findings not only confirm the importance of asset heterogeneity for market liquidity but also provide stylized facts for future theoretical studies. Third, our study of the Single Security Initiative sheds light on a landmark policy experiment in market design and provides evidence on how such interventions shape market liquidity.

We also contribute to an expanding literature on MBS market microstructure, which includes, in addition to those already cited above, Downing, Jaffee, and Wallace (2009), Gao, Schultz, and Song (2018), and Schultz and Song (2019). Our paper is particularly related to studies at the intersection of market liquidity and asset pricing. For example, Krishnamurthy and Vissing-Jorgensen (2013), Fusari, Li, Liu, and Song (2021), and He and Song (2020) study variation in agency MBS safety and liquidity premia.[6] We differ

[4]Theoretical models include Mendelson (1987), Pagano (1989), Chowdhry and Nanda (1991), Vayanos and Wang (2007), Vayanos and Weill (2008), Weill (2008), Hendershott and Mendelson (2000), Chao, Yao, and Ye (2018), Babus and Parlatore (2019), Chen and Duffie (2021), and Allen and Wittwer (2021). These studies typically focus on an environment with one asset traded at multiple potential venues, although Li and Song (2020) consider heterogeneous assets, more in line with the features of the TBA market.

[5]Most closely related, Huh and Kim (2020, 2021) and An, Li, and Song (2021a,b) analyze the connection between the market structure of MBS trading and MBS securitization and origination activities.

[6]A large asset pricing literature also studies the pricing of prepayment risk; see Levin and Davidson (2005), Gabaix, Krishnamurthy, and Vigneron (2007), Diep, Eisfeldt, and Richardson (2021), Boyarchenko, Fuster,

by examining liquidity premium differentials across agencies associated with market fragmentation and consolidation.

II Institutional Background and Economic Framework

II.A Institutional Setting

Agency MBS market. The agency MBS market is one of the largest and most active fixed-income markets in the world. The market finances 62% of U.S. home mortgage debt, and average MBS daily trading volume exceeds $200bn (sources: Urban Institute and SIFMA; see Fuster, Lucca, and Vickery 2021 for futher details). Guaranteed by Fannie Mae, Freddie Mac, and Ginnie Mae, agency MBS are effectively default-free; however they are subject to significant uncertainty about the timing of cash flows, known as prepayment risk, because agency mortgage borrowers are able to prepay their loans without penalty.

Agency MBS are traded through either the specified pool (SP) market where counterparties transact a particular security, or the to-be-announced (TBA) forward market where any MBS within an eligible set can be delivered to the buyer at settlement.[7] A TBA contract specifies, for example, a Fannie Mae 30-year fixed-rate MBS with a 4% security coupon; the particular MBS that the seller will deliver is identified only two days before settlement.[8] At any given time, there are tens of thousands of MBS outstanding, which differ vastly in prepayment characteristics (e.g., loan amounts, geography, and credit scores) and hence in fundamental values. By combining these heterogeneous MBS into a small number of cohorts, the TBA market provides a remarkably liquid venue for trading, with low transaction costs of only a few basis points (bp), compared to 60-80 bp for SP

and Lucca (2019), and Chernov, Dunn, and Longstaff (2018) among others.

[7]Most TBA-eligible MBS are so-called "pass-through" securities, which pay mortgage principal and interest net of servicing and guarantee fees to all investors. Pass-through securities can be pooled together to create structured MBS with customized prepayment and maturity profiles, which are not eligible for TBA delivery in general. Some pass-through MBS are also not TBA-eligible (e.g., "high-balance" pools where more than 10% of loan balances are mortgages with principal exceeding the national conforming loan limit.)

[8]TBA contracts have only one settlement date per month set by SIFMA (e.g., for 30-year Fannie Mae MBS, settlement day is typically around the 12th or 13th of the month).

trades (Bessembinder, Maxwell, and Venkataraman, 2013; Gao, Schultz, and Song, 2017). TBAs are also used for hedging by mortgage lenders and MBS investors. Consequently, the TBA market is significantly more active than the SP market, accounting for more than 90% of total agency MBS trading volume.

Although liquid, the TBA market features a cheapest-to-deliver issue, similar to Treasury futures, because trade prices are set without specifying which MBS will be ultimately delivered. Consequently, relatively high-value MBS within a TBA cohort are often traded on an individual basis in the SP market.[9] As shown theoretically by Fusari, Li, Liu, and Song (2021), enlarging MBS heterogeneity is expected to increase the share of MBS traded in the SP market and magnify the cheapest-to-deliver discount in the TBA market.

Fragmentation and consolidation. The mortgage giants Fannie Mae and Freddie Mac play similar roles in the agency MBS market — both agencies purchase qualifying "conforming" mortgages and issue MBS with a payment guarantee, and the two GSEs have similar underwriting standards and face common regulation.[10] Consequently, the population of loans backing Fannie Mae and Freddie Mac MBS are fundamentally very similar. Despite this similarity, as a result of historical factors, TBA trading was highly concentrated in the Fannie Mae segment of the market prior to the Single Security Initiative. This asymmetry was a significant concern for policymakers, because for example it meant that Freddie Mac was often forced to discount its guarantee fees to mortgage sellers to compensate for the lower liquidity of its MBS:

[9] An, Li, and Song (2021b) estimate that around half of newly-issued TBA-eligible MBS are first sold through the SP market. Although TBA trading volume greatly exceeds SP trading, most TBA trades are netted out before settlement and do not result in a physical delivery of securities.

[10] Fannie Mae and Freddie Mac are private but government-sponsored enterprises, and have been in public conservatorship since September 2008. Because of their size and quasi-government status, the GSEs' MBS credit guarantees are widely viewed as being implicitly backed by the federal government. For more background on Fannie Mae and Freddie Mac, see Acharya, Richardson, Nieuwerburgh, and Wright (2011) or Frame, Fuster, Tracy, and Vickery (2015). Ginnie Mae MBS instead have an *explicit* government guarantee, because Ginnie Mae is a government agency within the Department of Housing and Urban Development. While mortgages backing Fannie Mae and Freddie Mac MBS pools are fairly similar to one another, the Ginnie Mae population is more distinct because it comprises mortgages insured by the Federal Housing Administration (FHA), Veterans Administration (VA) and other federal agencies (e.g., FHA borrowers are typically lower income and have lower credit scores).

"Fannie Mae's MBS tend to trade at higher prices (with corresponding lower interest rate yields) than similar securities from Freddie Mac. This is mainly due to the liquidity benefit of a larger volume of Fannie Mae securities in the market. Freddie Mac is able to compete with Fannie Mae for business by offering market adjusted pricing (MAP) to its lenders that exchange loans for MBS. MAP provides a discount from the contractual ongoing guarantee fee based on the spreads between Fannie Mae and Freddie Mac MBS." (FHFA, 2015).

To improve market liquidity and level the playing field, the GSEs' regulator, the Federal Housing Finance Agency (FHFA), proposed the idea of unifying Fannie Mae and Freddie Mac TBA trading into a single market in its 2012 Strategic Plan for Enterprise Conservatorships (FHFA, 2012). At the same time, the FHFA announced an initiative to construct a Common Securitization Platform to replace Fannie Mae and Freddie Mac's separate proprietary systems. The FHFA confirmed its commitment to a single security in its 2014 strategic plan, and issued a Request for Input that outlined the security design on August 12, 2014, (FHFA, 2014). A detailed design was announced on July 11, 2016. (We use this date in our empirical analysis to mark the start of the UMBS transition period.)

The proposed consolidation was not without risk. In particular, market observers expressed concerns that consolidation could increase asset heterogeneity within each TBA cohort and drive trading from TBAs to the illiquid SP market, thereby magnifying fragmentation rather than reducing it. Cognizant of these concerns, the Single Security Initiative included several steps to align the security design and prepayment characteristics of Fannie Mae and Freddie Mac pools, with the goal of improving uniformity and reducing the risk of market unravelling.

Implementation of the Common Securitization Platform, known as "Release 1", was completed on December 8, 2016. On March 18, 2018, the FHFA announced that issuance of a common uniform MBS through the Common Securitization Platform ("Release 2") would begin in June of the following year. Issuance of UMBS ultimately began on June 3, 2019. Since that date, all TBA-eligible MBS issued by Fannie Mae or Freddie Mac are issued as UMBS and traded through the same UMBS TBA contracts.[11] Because MBS can be traded on the TBA market up to three months before issuance, UMBS forward trading began on March 4, 2019. Post-UMBS, Fannie Mae and Freddie Mac TBA trading is now completely consolidated: a TBA seller can deliver MBS issued by either agency, or a combination, when the forward contract is settled.

II.B Economic Framework and Hypotheses

In this section, we develop testable hypotheses framed by theories of endogenous market concentration and fragmentation, including Mendelson (1982, 1985), Pagano (1989), Chowdhry and Nanda (1991), Vayanos and Wang (2007), Vayanos and Weill (2008), Weill (2008), and Li and Song (2020). While the specific mechanics of these models differ, a consensus prediction is that trading will endogenously concentrate in one segment due to liquidity network externalities, and consequently that segment will feature an endogenous liquidity premium relative to other parts of the market.

These theories usually model ex-ante identical markets and hence are silent as to which market will become the focal venue for trading. Conceivably, if one venue features some (even slight) ex-ante advantage vis-à-vis another, network externality would amplify its advantage and cause this venue to become the dominant market for trading. In our context Fannie Mae is older and historically larger than Freddie Mac and became focal once it began to finance its purchases through the MBS market (see Appendix A for historical details). Thus, these predictions can be summarized in our setting as follows:

Hypothesis 1 ***[Effects of fragmentation on secondary market]:*** *Prior to UMBS, secondary market liquidity of Fannie Mae MBS exceeds that of Freddie Mac MBS, and Fannie Mae MBS have a higher liquidity premium.*

[11] The design of UMBS mimics Fannie Mae's legacy securities. All existing Fannie Mae pools were automatically converted to UMBS on the June 3 implementation day, while legacy Freddie Mac pools can be exchanged for UMBS, with compensation provided to the investor for differences in payment timing (UMBS pools have a 55 day delay between the scheduled mortgage payment date and the payment of cash flow to investors, rather than the 45 day delay used for legacy Freddie Mac pools). UMBS disclosure rules generally follow those previously set by Freddie Mac.

Although the above models focus on secondary market trading, the same network externality mechanism can also be applied to security issuance in the primary market. There is also likely a feedback channel between secondary and primary markets: greater secondary market liquidity would support a higher primary market share and securitization fee income, which in turn further strengthens secondary market liquidity. These predictions are summarized in the following hypothesis:

Hypothesis 2 ***[Effects of fragmentation on primary market]:*** *Prior to UMBS, Fannie Mae MBS issuance exceeds Freddie Mac. Fannie Mae guarantee fee income is also higher than Freddie Mac.*

Next, we consider effects of the consolidation of TBA trading under the Single Security Initiative. By construction, consolidation would result in full convergence in TBA liquidity and prices *after* implementation. Moreover, in dynamic models of market liquidity, market prices and trading decisions today reflect investors' expectations about future prices and liquidity (Amihud and Mendelson, 1986; Huang, 2003; Vayanos, 1998). Consequently, we expect prices and trading volume between Fannie Mae and Freddie Mac to begin to converge *in advance of* final implementation. Similar to the hypotheses above, we consider convergence in both primary and secondary markets:

Hypothesis 3 ***[Market consolidation and convergence]:*** *The Single Security Initiative would reduce the differential between Fannie Mae and Freddie Mac in secondary market TBA liquidity, liquidity premia, primary market issuance, and guarantee fees. This convergence begins to occur prior to the final implementation of market consolidation.*

Although Freddie Mac would stand to benefit more from market consolidation, as the previously thin market, a network externality view of liquidity would suggest that both Fannie Mae and Freddie Mac liquidity should benefit from consolidation. However, as we have discussed, a less benign outcome is also possible because of the adverse effects of enlarging asset heterogeneity and the risk that trade might migrate to the less-liquid SP market. This would in turn reduce liquidity for higher-value MBS — especially Fannie Mae MBS that historically had slightly more favorable prepayment characteristics and higher values than Freddie Mac — and might even reduce market liquidity in aggregate (Li and Song, 2020). The below hypothesis, however, states the expected effects of market consolidation if steps to harmonize MBS between Fannie Mae and Freddie successfully mitigated these effects:

Hypothesis 4 ***[Market consolidation, asset heterogeneity, and network externality]:*** *(i) Prepayment characteristics of Fannie Mae and Freddie Mac MBS converge, and there is no migration of MBS trading from TBA to SP markets; (ii) liquidity for Fannie Mae and Freddie Mac MBS both improve as a result of market consolidation.*

III Data and Summary Statistics

In this section, we describe the data and empirical measures used in our analysis and present summary statistics.

III.A Data

We use three main data sets: (1) eMBS, which provides data on MBS issuance, outstanding balance, realized prepayment rates, and TBA eligibility; (2) TRACE data on agency MBS secondary market trades (we use the supervisory version of TRACE, which does not truncate trade sizes and includes individual dealer identifiers); and (3) J.P. Morgan Markets, which provides data on MBS prices, yields, and prepayment forecasts. The main variables of interest we use are described below.

MBS trading volume and transaction costs. We use TRACE to measure trading volume, typically at a monthly frequency given that TBA contracts settle on a monthly cycle. We primarily focus on the most active front-month TBA contracts for 30-year Fannie Mae, Freddie Mac and Ginnie Mae MBS.[12] Similarly, we compute monthly total SP trading

[12] We keep only regular good-delivery outright TBA trades with standard fixed coupon payments and without stipulations. Therefore we exclude dollar rolls, stipulated TBA trades, and trades with quarter or non-standard coupon rates.

volume by summing over individual SP trades. We measure TBA transaction costs by the standard round-trip trading cost computed as the difference between dealers' buy and sell prices for customer trades, again measured using TRACE (Bessembinder, Maxwell, and Venkataraman, 2013; Friewald, Jankowitsch, and Subrahmanyam, 2017; Gao, Schultz, and Song, 2017). These measures are all available from May 2011 onward, when TRACE began reporting data on agency MBS trades.

MBS prices and yields. We obtain monthly price series for front-month 30-year Fannie Mae, Freddie Mac and Ginnie Mae TBA contracts from J.P. Morgan. These series are available from January 1998 onward.[13] When comparing Fannie Mae and Freddie Mac prices, we take into account the fact that, prior to UMBS, Freddie Mac MBS paid principal and interest to investors with a 45-day payment delay, compared with 55 days for Fannie Mae. We account for this timing difference by adjusting Fannie Mae MBS prices upward by 2/32nds of a percentage point, following a widely used market rule of thumb as an approximation of the present value of this payment timing difference (TBAs are traded in increments of a "tick," equal to 1/32nd of a percent). This may be a slight over-adjustment in our sample, when interest rates are at historically low levels; to the extent this is the case, our estimate of the liquidity premium of Fannie Mae MBS relative to Freddie Mac MBS would tend to be slightly conservative.

We further obtain time-series of option-adjusted spread (OAS) by agency and coupon computed by J.P. Morgan based on these TBA prices. OAS is a spread added to the term structure of interest rates such that the present value of the expected future cash flows of an MBS (averaged across different interest rate paths and taking into account prepayment along each path) equals its market price. As also used in Gabaix, Krishnamurthy, and Vigneron (2007), Boyarchenko, Fuster, and Lucca (2019), and Song and Zhu (2019), OAS is equal to a weighted average of future expected excess returns after hedging for interest rate risk and contains liquidity premium as a component. It also embeds a non-interest-

[13] As a major MBS dealer, J.P. Morgan collected data on MBS trades they intermediated well before FINRA began collecting transaction data via TRACE in May 2011. Over the period since TRACE became available, we find that J.P. Morgan prices closely correspond to TRACE prices.

rate-driven prepayment risk premium, an issue we shall discuss further later. (Note: OAS already accounts for the payment timing difference between Fannie Mae and Freddie Mac mentioned earlier). We use OAS series based on the Libor term structure, although results using Treasury OAS are similar.

MBS issuance amount and outstanding balance. We measure primary market activity using new issuance amount and outstanding balance for 30-year Fannie Mae, Freddie Mac, and Ginnie Mae MBS. These measures are constructed by aggregating security-level series from eMBS, which are available at monthly frequency for our maximum sample period from January 1998 to February 2020.

Guarantee Fees. We collect quarterly data on guarantee fees from Fannie Mae and Freddie Mac's 10-Q filings. (We also collect 10-K filings, although we do not use them for our primary analysis because they report annual rather than quarterly data). These filings report average guarantee fees on the agency's entire portfolio, as well as guarantee fees on new purchases in the quarter. These reported fees reflect both periodic and up-front guarantee fees charged by the GSE as compensation for providing a payment guarantee on the MBS pool. Up-front fees are amortized over the expected life of the mortgage pool. Fees are reported on an annualized basis.

MBS prepayment rates. We obtain monthly realized prepayment rates of 30-year Fannie, Freddie, and Ginnie TBA-eligible MBS from eMBS. We also obtain prepayment rate forecasts from J.P. Morgan, based on its prepayment model and estimates of the actual set of pools likely to be delivered into TBA contracts. These monthly prepayment rates are measured as conditional prepayment rates (CPRs), which measure annualized prepayments as a percentage of the scheduled loan balance (a 10% CPR means that at the current speed, 10% of the scheduled pool balance is projected to prepay over the course of a year).

III.B Summary statistics

Table 1 reports summary statistics for the main variables of interest — trading volume, issuance, and outstanding balance, transaction cost, price, OAS — aggregating across Fannie Mae and Freddie Mac. For the three volume measures, we take the sum across the two agencies, while for prices, yields and transaction costs, we report the average. Statistics are reported in aggregate as well as for different coupon cohorts across the coupon stack (recall that TBAs trade in 50 bp increments). Similar to the literature (Diep, Eisfeldt, and Richardson, 2021), we classify each coupon based on its "moneyness", that is, the difference between the coupon rate and the "current coupon" which is the coupon for a synthetic TBA contract trading exactly at par. (Current coupon data are obtained from J.P. Morgan Markets.) For example, if the current coupon is 2.86%, the 2.5% TBA contract would be labeled as CC-1, the 3% TBA contract as CC+1, and so on. To focus on actively traded MBS, we limit the sample to coupons with moneyness between CC-2 and CC+6. Hence, the resulting sample is an unbalanced panel with more observations for more active cohorts, usually those near par.

Turning to the first three columns of Table 1, total monthly TBA trading volume summed across Fannie Mae and Freddie Mac averages $1.08 trillion (tr) (since 2011), while the sum of primary market issuance and outstanding balance is $50.32 billion (bn) and $2.11 tr, respectively (since 1998). Breaking down these statistics across the coupon stack, trading is indeed most active for coupons near par, and particularly for the coupons just above par, where new issuance is typically concentrated. Specifically, average TBA trading volume, issuance, and outstanding balance are about $300 bn, $15 bn, and $410 bn respectively for CC+1 and CC+2, but decrease to less than $50 bn, $2 bn, and $250 bn for coupon cohorts including and beyond CC-2 and CC+4. (The variation in outstanding balance across cohorts is smaller than that for issuance because the stock of MBS reflects securities issued at different points in time over a range of interest rate environments.)

The fourth column of Table 1 reports daily average of TBA round-trip trading cost (RTC) for each moneyness cohort. We find that TBA trading cost is less than one basis point for

Table 1: **Summary Statistics**

	Trading (*bil*)	Issuance (*bil*)	Outstanding (*bil*)	RTC (cents per 100*par*)	Price (% of par)	OAS (bp)
Aggregate						
Mean	822.4	50.32	2111.53			
N	94	254	254			
CC-2						
Mean	25.22	5.68	182.85	.0112	95.62	21.69
N	43	165	232	278	204	203
CC-1						
Mean	101.44	12.2	359.68	.0054	98.7	18.97
N	75	219	244	846	226	225
CC+1						
Mean	227.57	15.79	434.64	.0057	101.31	16
N	91	250	253	1625	235	235
CC+2						
Mean	280.36	14.55	413.87	.0033	103.47	18.4
N	93	249	250	1922	215	215
CC+3						
Mean	151.6	5.39	356.11	.0003	105.26	20.99
N	94	239	240	1798	191	191
CC+4						
Mean	53.33	1.3	236.88	.0150	106.98	26.46
N	94	211	236	1245	161	161
CC+5						
Mean	19.19	.27	151.7	.0353	108.78	31.22
N	94	131	215	723	131	131
CC+6						
Mean	9.19	.12	98.04	.0406	110.16	36.22
N	83	54	191	375	122	122

The first three columns report the monthly time series mean of front-month TBA trading volume, issuance amount, and outstanding principal balance of 30-year agency (sum of Fannie Mae and Freddie Mac) MBS, respectively, at the aggregate level in the first row and moneyness-cohort level in the remaining rows. The fourth column reports the daily time series mean of the round-trip trading cost of front-month TBA contracts of 30-year agency (average across Fannie Mae and Freddie Mac) MBS at the moneyness-cohort level. The last two columns report the monthly series mean of price (per $100 of principal) and Libor OAS (in basis points) of front-month TBA contracts of 30-year agency (average across Fannie Mae and Freddie Mac) MBS at the moneyness-cohort level. We restrict the sample to moneyness cohorts of CC-2 to CC+6. The sample period is May 2011 to February 2019 for TBA trading volume and RTC, and January 1998 to February 2019 for issuance amount, outstanding balance, price, and OAS.

coupon cohorts near par and about 2-4 basis points even for in-the-money cohorts beyond CC+4, generally consistent with estimates in Bessembinder, Maxwell, and Venkataraman (2013) and Gao, Schultz, and Song (2017). The fifth and sixth columns report the average TBA price and OAS. We observe that average TBA price increases with moneyness, while OAS exhibits a "smile" pattern consistent with Boyarchenko, Fuster, and Lucca (2019) — OAS exceeds 20 bp for both out-of-the-money (CC-2) and in-the-money cohorts (beyond CC+3) but is lower than 20 bp for cohorts relatively near par (CC-1, CC+1, and CC+2). (See also Diep, Eisfeldt, and Richardson (2021) and Fusari, Li, Liu, and Song (2021) for detailed analyses of cross-coupon variation in MBS pricing.)

IV Effects of Market Fragmentation and Concentration

In this section, we document the effects of the market fragmentation that existed prior to UMBS. We focus on the period before July 2016, when the FHFA set a firm timetable and design for the Single Security Initiative as discussed in Section II. (Our results are not particularly sensitive to this choice of cutoff date, however, as we show below.) Although the concentration of secondary market activity in the Fannie Mae segment was well-known to market practitioners, our analysis below is, to the best of our knowledge, the first to comprehensively measure the effects of this liquidity pooling and its effects on MBS secondary and primary markets.

IV.A Secondary Market Trading

The left panel of Figure 1 plots monthly time series of total TBA trading volume, and provides an intuitive sense of the concentration of MBS trading in the Fannie Mae segment — TBA volume is consistently an order of magnitude larger for Fannie Mae than Freddie Mac throughout the sample period. As a benchmark, the right panel plots aggregate outstanding MBS balances for the two agencies. The float of securities outstanding is also larger for Fannie Mae, but the difference is much smaller than the gap in trading volume, reflecting the fact that Fannie Mae TBAs were the thick market for trading and the primary

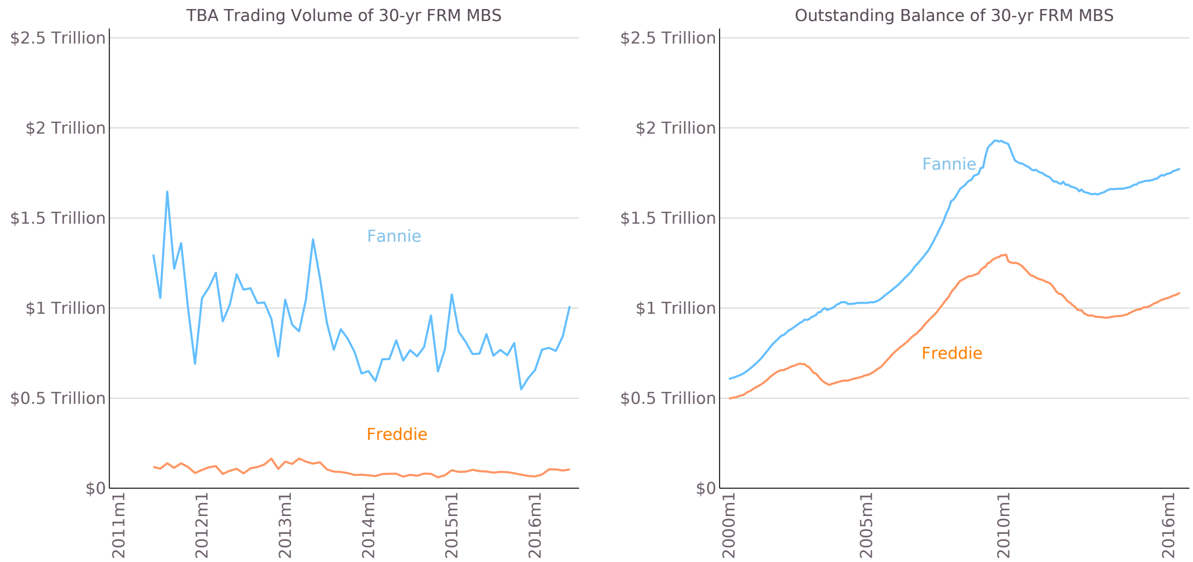

Figure 1: **TBA Trading Volume and Outstanding Balance**

The left panel plots monthly time series of front-month TBA trading volume of 30-year Fannie Mae and Freddie Mac MBS, respectively, from June 2011 to June 2016. The right panel plots monthly time series of outstanding balance of TBA-eligible Fannie Mae and Freddie Mac 30-year MBS, respectively, from January 2000 to June 2016.

venue for hedging and speculating.

To quantify these effects, the first two columns of Table 2 estimate the average (log) difference in aggregate TBA trading volume and turnover between Fannie Mae and Freddie Mac. Fannie Mae TBA trading volume is 10.9 times ($\approx e^{2.44}$) larger than that of Freddie Mac, while turnover – trading volume scaled by outstanding MBS balance – is 6.1 times ($\approx e^{1.81}$) larger. The third column then reports the average gap in transaction costs (RTC) across days and coupons in the TBA coupon stack. Fannie Mae TBA trading costs averaged about one basis point lower than Freddie Mac, in proportionate terms a significant difference compared to average Freddie Mac trading costs of about two basis points reported in the row "Mean (Freddie Mac)".

Next, we test whether Fannie Mae MBS commands a liquidity premium relative to Freddie Mac in the pre-UMBS era. We estimate regressions of the Fannie Mae–Freddie

Table 2: **Fannie Mae–Freddie Mac Gap in Secondary Market Liquidity**

	Log($\frac{\text{Trading}}{\text{Volume}}$)	Log($\frac{\text{Trading Volume}}{\text{Balance}}$)	Round Trip Transaction Cost	Price	OAS
Frequency	Monthly	Monthly	Daily	Monthly	Monthly
Aggregation Level	Aggregate	Aggregate	Cohort	Cohort	Cohort
Fannie-Freddie Gap	2.32***	1.81***	-0.011***	0.25***	-5.42***
	(0.04)	(0.04)	(0.002)	(0.02)	(0.52)
Mean (Freddie Mac)	75.51 bil	.074	.020	102.5	21.44
Observations	62	62	5749	1232	1232
Cohort x CPR Diff				X	X

The first two columns report the average (log) difference in TBA trading volume and turnover (TBA trading volume divided by outstanding balance) between Fannie Mae and Freddie Mac MBS, respectively, obtained by monthly time series regressions at the aggregate level (summed across coupon cohorts). The third column reports the average difference in round-trip trading cost of Fannie Mae and Freddie Mac TBA trading, obtained by regressions at the coupon×day level. The fourth and fifth columns report the average difference in price and OAS, respectively, of Fannie Mae and Freddie Mac TBA contracts, obtained by regressions at the cohort×month level, controlling for moneyness cohort FE and its interaction with the difference in prepayment rate forecast (CPR) of Fannie Mae and Freddie Mac MBS. The sample means of all these measures for Freddie Mac MBS are also reported. The sample period is June 2011 to June 2016 for TBA trading volume and round-trip trading cost, and January 1998 to June 2016 price and OAS. Standard errors are clustered by month and adjusted for serial correlation using the estimator of Driscoll and Kraay (1998) with four lags following the lag selection procedure in Hoechle (2007). * is $p<0.10$, ** is $p<0.05$, *** is $p<0.01$.

Mac gap in price and OAS respectively for month t and moneyness cohort i, on a constant, including as controls the difference in prepayment rate forecast interacted with a vector of moneyness dummies ($I_{moneyness=i} \times$ CPR difference$_{it}$) as controls. These controls ensure that the constant term measures the average difference in TBA price and OAS conditional on a zero difference in prepayment speed between the two GSEs. This is important because we want to isolate the *liquidity* component of the price and yield difference between the two agencies and strip out any difference due to prepayment risk. Price is certainly sensitive to prepayment speed for TBA coupons not trading at par, and although OAS in principle already accounts for prepayment speed and risk, it may do so imperfectly because it is a model-based measure. The J.P. Morgan prepayment rate forecasts are used here because

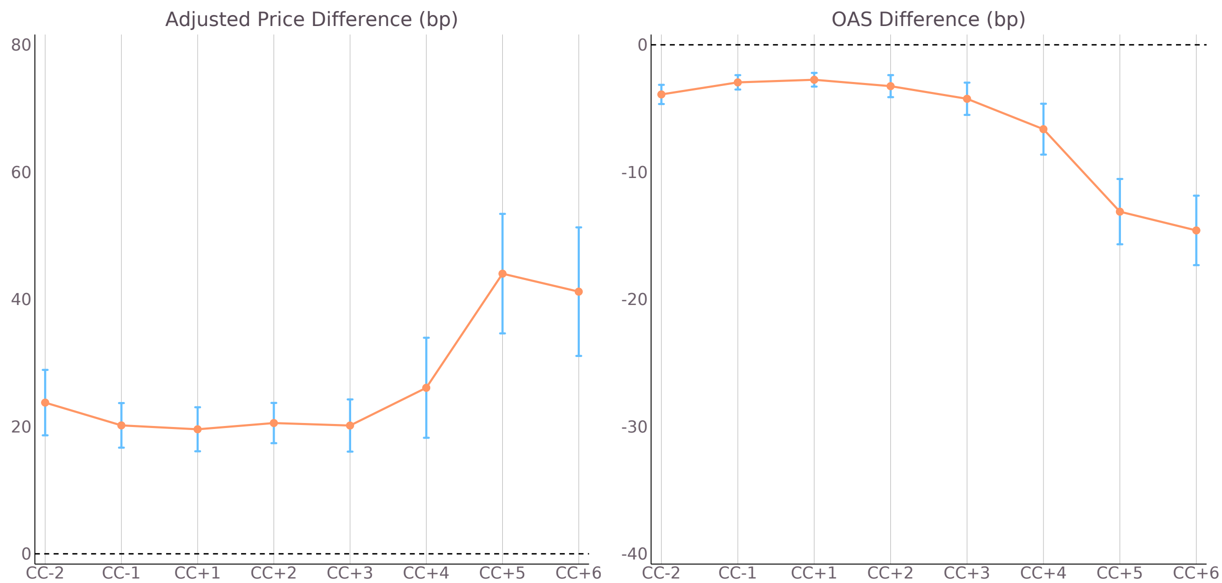

Figure 2: **Fannie Mae–Freddie Mac Gap in Price and OAS Across Coupon Cohorts**
This figure plots the average difference in price (left panel) and OAS (right panel) of Fannie Mae and Freddie Mac front-month TBA contracts for each moneyness cohort, obtained by monthly time series regressions at the moneyness cohort level, controlling for the difference in prepayment rate forecast (CPR) of Fannie Mae and Freddie Mac MBS. The sample period is January 1998 to June 2016 price and OAS. The 95% confidence intervals based on errors clustered by month are also reported.

they are measured exactly for the set of MBS likely to be delivered into TBA contracts.

Results are reported in the fourth and fifth columns of Table 2. The average price gap is +25 cents per $100 par value, while the average OAS gap is -5.4bp. These estimates are consistent with one another considering the average price-yield multiplier of about 5 estimated by Fuster, Lo, and Willen (2017).

Next we investigate the price and OAS results further by estimating disaggregated coefficients by moneyness coupon. Figure 2 reports the average Fannie-Freddie gap in price (left panel) and in OAS (right panel) estimated for each moneyness level (-1, +1, +2 etc.), again controlling for the prepayment speed differential. We observe that there is a consistent gap in price and OAS across the coupon stack, with a price gap of 20 cents, and OAS gap of about 3-5 bp, respectively, for coupons close to par including CC-1, CC+1, and

CC+2. This is important additional evidence that our estimates reflect liquidity effects rather than prepayment risk premia, because the prepayment risk premium is negligible for MBS trading at par (Boyarchenko, Fuster, and Lucca, 2019) and because the price effect of faster prepayment flips signs for bonds trading at a discount rather than a premium. Further, these results in Figure 2 show that the greater liquidity of Fannie Mae TBAs has a particularly large effect on price and yield for less-liquid coupons trading far from par.

To sum up, consistent with Hypothesis 1, the results in this section show that Fannie Mae MBS were significantly more liquid prior to the Single Security Initiative, with much larger TBA trading volume and lower transaction costs. As a result Fannie Mae MBS commanded a substantial liquidity premium over comparable Freddie Mac securities.

IV.B Primary Market Issuance and Guarantee Fees

Next we quantify how these differences in secondary market liquidity in the pre-UMBS era affected primary market issuance and the guarantee fees Fannie Mae and Freddie Mac were able to generate, as formulated in Hypothesis 2. Estimates are reported in Table 3, based on monthly MBS issuance data from J.P. Morgan Markets and quarterly guarantee fees collected from Fannie Mae and Freddie Mac's 10-Q filings.

The first column shows that Fannie Mae's liquidity advantage was associated with significantly higher primary market issuance. The log difference between Fannie Mae and Freddie Mac is 0.43; in dollar terms, Fannie Mae monthly issuance averaged $32 billion, more than 50 percent higher than Freddie Mac ($20 billion). These are averages between January 2000 and June 2016, although the estimates are similar measured over a shorter period just prior to UMBS (average log difference = 0.44 between January 2013 and June 2016).

The other columns of Table 3 show that Fannie Mae was able to benefit from its liquidity advantage by charging higher guarantee fees than its competitor. The guarantee fee differential is 8.4bp of the mortgage portfolio across the entire stock of MBS issued by each GSEs, measured from 2013Q1 to 2016Q2, while the differential on newly issued MBS averaged 5.4bp. (The latter measure is arguably cleaner since it is not affected by

Table 3: **Fannie Mae–Freddie Mac Gap in Issuance and Guarantee Fees**

	log (Issuance)	Guarantee fees: Full portfolio	Guarantee fees: New purchases	Guarantee fees: New purchases [risk-adjusted]
Fannie-Freddie gap	0.43***	8.48***	5.37***	4.54***
	(0.03)	(1.07)	(0.44)	(0.43)
Sample Mean	$20.47bn	31.41	54.37	45.45
Observations	198	11	11	11

Average (log) difference in monthly MBS issuance between Fannie Mae and Freddie Mac (data source: J.P. Morgan), and average difference in quarterly guarantee fees in basis points of unpaid loan balance, reflecting the sum of periodic g-fees and amortized up-front fees (data source: Fannie Mae and Freddie Mac 10-Q filings). Column 2 measures guarantee fees on the GSEs entire outstanding portfolio; Column 3 measures guarantee fees on mortgage purchased in the most recent quarter; Column 4 measures guarantee fees on new purchases after netting out credit risk effects by subtracting off the periodic value of loan-level price adjustments (LLPAs). LLPAs derived from loan-level data combined with LLPA pricing matrices reported by Fannie Mae; see Appendix B for methodology. Sample period is January 2000 to June 2016 for issuance, and 2013Q1 to 2016Q2 for guarantee fees. Standard errors are adjusted for serial correlation using the estimator of Driscoll and Kraay (1998) with four lags (issuance) or two lags (guarantee fees) following the lag selection procedure in Hoechle (2007). * is $p < 0.10$, ** is $p < 0.05$, *** is $p < 0.01$.

composition effects across MBS vintages). These results are consistent with Hypothesis 2 and with the institutional discussion in Section II.A that noted Freddie Mac would regularly offer loan sellers discounts to offset the lower liquidity of its MBS.

These fee differences are quantitatively important given the enormous size of the agency MBS market. Freddie Mac guaranteed about $1.5tr in single-family MBS in 2016, shortly before UMBS implementation. A 5bp gap in guarantee fees therefore translates to an annual income loss of $750 million. This simple calculation is consistent with Goodman and Ranieri (2014), who estimate that market-adjusted pricing discounts cost Freddie Mac as much as $1 billion annually prior to UMBS, putting it at a significant competitive disadvantage compared to Fannie Mae.

It is important to confirm that these guarantee fees differentials are driven by liquidity effects rather than differences in credit risk. Guarantee fees were insensitive to credit risk prior to the 2008 financial crisis (Hurst, Keys, Seru, and Vavra, 2016), but after the crisis, the

GSEs introduced "loan-level price adjustments" (LLPAs), that is, additional up-front fees based on loan risk (e.g., bins of loan-to-value and credit score). Thus, if a GSE securitizes riskier loans it will tend to have higher average guarantee fees.

We net out these up-front LLPAs in column 4 of Table 3. We first estimate the LLPA for each mortgage securitized by the GSEs from 2013 onwards by combining loan-level data from eMBS with LLPA pricing matrices published annually by Fannie Mae (see Appendix for details). We then collapse these estimates to compute the average LLPA by agency and quarter and convert them to an equivalent periodic fee assuming a price-yield multiplier of 5, consistent with the estimates of Fuster, Lo, and Willen (2017). We then subtract this periodic-equivalent LLPA from the new-purchase guarantee fee by agency and quarter. The difference in LLPA-adjusted guarantee fees is slightly smaller than the unadjusted difference (4.5bp compared to 5.4bp) reflecting Fannie Mae's somewhat riskier portfolio, but is still economically similar and statistically significant.

To sum up, these results indicate that the fragmentation of the TBA market prior to UMBS had significant consequences for the primary market. Freddie Mac's lower guarantee fee income can be viewed as a measure of the cost of the loss of liquidity network externalities, a cost which was ultimately borne by taxpayers given the government backing of the GSEs under their conservatorships (Frame, Fuster, Tracy, and Vickery, 2015). A primary objective of the Single Security Initiative was to eliminate this cost of fragmentation by consolidating the Fannie Mae and Freddie Mac TBA markets into one. We now turn to a detailed analysis of the effects of this market consolidation reform.

V Effects of Market Consolidation

In this section, we document the effects of market consolidation as a result of the Single Security Initiative.

V.A Convergence between Fannie Mae and Freddie Mac MBS

By design, UMBS implementation ultimately resulted in full convergence in TBA liquidity between Fannie Mae and Freddie Mac. In this section however we investigate the extent to which this convergence began in anticipation of UMBS implementation, as formulated in Hypothesis 3. In particular, we examine changes of TBA liquidity and prices in the transition period from July 2016 (when the FHFA set a firm timetable for the Single Security Initiative) to February 2019 (just before UMBS TBA trading began).

Specifically, we estimate time-series regressions of the Fannie Mae–Freddie Mac gap in TBA trading volume and turnover on three time dummies for July 2016 to June 2017, July 2017 to June 2018, and July 2018 to February 2019, respectively, with July 2015 to June 2016 as the base period. Hence, the regression coefficients on the three time dummies capture the change of the gap in the respective period relative to the base period. As reported in the first two columns of Table 4, the Fannie Mae–Freddie Mac gap in TBA trading volume and turnover in each of the three transition periods reduced relative to the pre-period. The reduction is statistically significant in two of the three periods, ranging from 12% to 24%.

We estimate similar regressions for the Fannie–Freddie gap in RTC, price, and OAS (RTC_{it}^{Gap}, $Price_{it}^{Gap}$, and OAS_{it}^{Gap}), controlling for moneyness cohort FE and its interaction with prepayment speed differential like those for Table 2. We also include some time series factors, such as the Baa-Aaa corporate bond yield spread and agency debt-swap spread, to control for time-varying risk premiums (Boyarchenko, Fuster, and Lucca, 2019). As reported in the third column, the change in the Fannie Mae–Freddie Mac gap in trading costs is quantitatively small and typically statistically insignificant. However, in the fourth and fifth columns, we observe that the Fannie Mae–Freddie Mac gap in price and OAS shrank significantly, by about 20-30 cents per $100 par value and 4.5-6.5 basis point respectively, reversing essentially all of the pre-transition gap in price and yield. Notably, the coefficients become larger over time, indicating greater convergence as the UMBS implementation date approaches. These results are consistent with the idea that TBA prices adjusted in anticipation of the full liquidity convergence to occur in mid-2019.

Table 4: **Convergence of Fannie Mae and Freddie Mac MBS**

	Log (Volume)	Log (Volume/Balance)	RTC	Price	OAS	Log (Issuance)	G-Fee
2016/07 to 2017/06	-0.283***	-0.247***	-0.000	-0.158***	3.443***	-0.042	-3.367*
	(0.039)	(0.043)	(0.008)	(0.036)	(0.797)	(0.045)	(1.945)
2017/07 to 2018/06	-0.165**	-0.105	0.009	-0.196***	4.251***	-0.024	0.367
	(0.066)	(0.068)	(0.008)	(0.037)	(0.812)	(0.056)	(2.309)
2018/07 to 2019/02	-0.311***	-0.234***	0.018**	-0.305***	6.692***	-0.025	2.033
	(0.033)	(0.033)	(0.007)	(0.032)	(0.686)	(0.029)	(2.482)
2019/03 to 2021/12						-0.191***	-5.942***
						(0.049)	(2.258)
Observations	44	44	3954	348	348	78	17
Cohort FE			X	X	X		
Cohort x CPR Diff				X	X		
Controls			X	X	X		

The first two columns report results of monthly time series regressions of the Fannie Mae–Freddie Mac gap in TBA trading volume and turnover (trading volume divided by outstanding balance), respectively, on three time dummies. The third column reports the result of regressing the Fannie Mae–Freddie Mac gap in round-trip trading cost on the three time dummies at the day×cohort level, controlling for moneyness cohort FE, its interaction with the Fannie Mae–Freddie Mac difference in prepayment rate forecast and time series variables including the Baa-Aaa corporate bond yield spread and agency debt-swap spread, while the fourth and fifth columns report the results of similar regressions for the Fannie Mae–Freddie Mac gap in price and OAS at the month×cohort level. The sixth column reports the result of monthly time series regressions of the Fannie Mae–Freddie Mac gap in issuance amount on the three time dummies for the transition period and the time dummy for the post-UMBS period. The sample period is July 2015 to February 2019 for the first five columns, and July 2015 to February 2020 for the last column. Standard errors clustered by month are reported in parentheses. Significant at *p<0.10, **p<0.05, ***p<0.01.

Turning to the primary market, the sixth column of Table 4 reports estimates for the Fannie Mae–Freddie Mac gap in issuance. It is possible to study this outcome variable both before and after UMBS implementation, because the two GSEs still issue their own distinct securities in the primary market even in the post-implementation period. We observe that the gap in issuance amount does not change significantly in the transition period but declines significantly, by about 20% on average over the period after UMBS trading begins, through to the end of 2021. For example in calendar 2021 Freddie Mac's MBS guarantee portfolio grew by 19.3%, compared to only 8.6% for Fannie Mae (sources: Fannie Mae and Freddie Mac monthly volume summaries) and in some months Freddie Mac residential MBS issuance exceeded Fannie Mae in absolute terms, in sharp contrast to the pre-UMBS period.

The final column estimates the effect of UMBS implementation on guarantee fees. Similar to primary market issuance, we do not observe any convergence in guarantee fees prior to UMBS implementation. However, the gap declined significantly, by 5.9 bp, immediately after UMBS implementation was complete. Since mid-2019 the difference in guarantee fees between the two agencies has been negligible.

V.B MBS Harmonization

In this section, we present three pieces of evidence that the actions taken by the FHFA to align the fundamentals of the MBS issued by the two GSEs were able to reduce asset heterogeneity and its potential adverse effects; see Hypothesis 4 (i).

Realized prepayment speeds. First, Figure 3 plots monthly series of realized prepayment rates of Fannie Mae and Freddie Mac MBS, respectively, from June 2014 to June 2019. These are calculated as the average (weighted by outstanding balance) across all outstanding 30-year fixed-rate MBS for each month and each agency. The difference in prepayment rates between Fannie Mae and Freddie Mac MBS is quite low, less than 1% throughout the period. Relative to the period before June 2016, the difference diminishes slightly, especially after UMBS implementation.

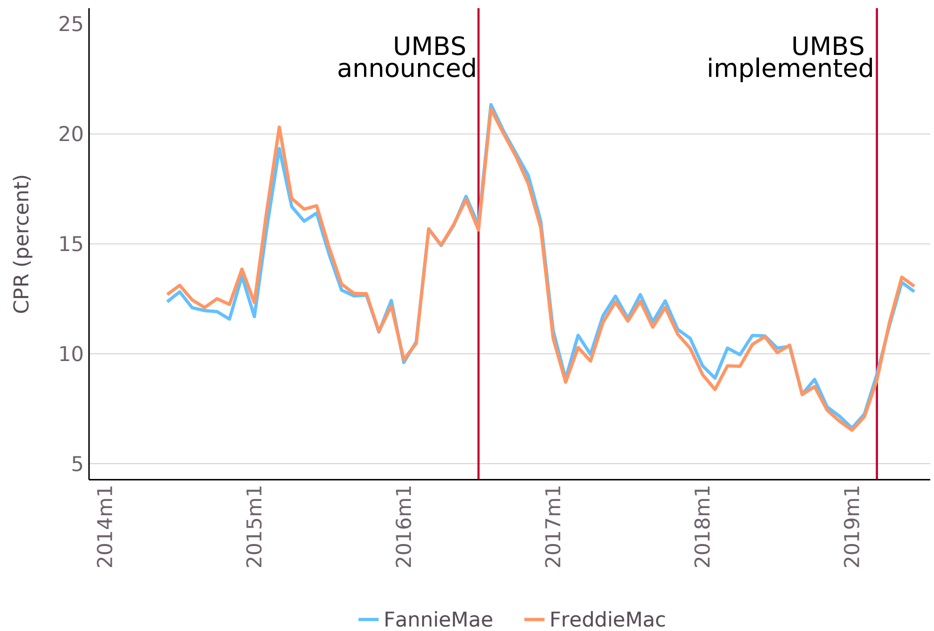

Figure 3: **Fannie–Freddie Gap in Prepayment Speed**

This figure plots time series of (annualized) monthly realized prepayment rates of Fannie Mae and Freddie Mac MBS, respectively, calculated as the average across all outstanding 30-year fixed-rate MBS (weighted by outstanding balance). The sample period is June 2014 to June 2019. The vertical lines indicate June 2016 when the FHFA set a firm timeline for the Single Security Initiative and March 2019 when UMBS TBA trading started.

UMBS TBA settlements. Second, we examine whether Fannie Mae and Freddie Mac MBS are equally likely to be delivered to settle UMBS TBA contracts. Looking into the actual MBS delivered into TBA contracts, this "revealed-preference" approach directly examines whether investors treat Freddie Mac and Fannie Mae MBS as of homogeneous values given that TBA contracts are settled on a cheapest-to-deliver basis.

Data on which specific MBS are delivered to settle TBA contracts are not widely available for use in academic research. However, our analysis takes advantage of the availability of security-level holdings of MBS by the Federal Reserve, which are purchased exclusively through TBA contracts. By merging the Federal Reserve's holdings data with information on MBS characteristics from eMBS, we are able to recover a comprehensive history of settlements associated with the Federal Reserve's MBS asset purchases via the

Table 5: **Settlements of the Federal Reserve's TBA Purchases**

	TBA Delivery/Outstanding	TBA Delivery/Issuance$_{t-3,t}$	TBA Delivery/Issuance$_{t-12,t}$
Fannie Mae	-0.003	-0.063	-0.002
	(0.003)	(0.068)	(0.005)
Mean	0.022	0.331	0.045
N	318	159	228

This table reports results of regressing the amount of MBS delivered to settle the TBA contracts purchased by the Federal Reserve on the Fannie Mae dummy. The TBA delivery amount is normalized by the outstanding balance (in the first column), cumulative issuance amount over the previous three months of the settlement month (in the second column), and cumulative issuance amount over the previous twelve months of the settlement month (in the third column) for Fannie Mae and Freddie Mac separately. The sample period is from June 2019 to February 2020.

TBA market. Details of our methodology are provided in Appendix C. We cross-validate our methodology by comparing our estimates to actual settlement data provided by the New York Fed Markets Group for a five month period in 2020. Over this period we match the direct settlement data almost exactly.

We collapse the UMBS TBA settlement data to the coupon (i) $\times$ agency (a) $\times$ month (t) level, and estimate whether Freddie Mac MBS are delivered disproportionately often by regressing TBA deliveries / MBS stock$_{a,i,t}$ on a Fannie Mae dummy, controlling for coupon and month fixed effects. We normalize the delivery amount by the total stock of MBS; we also normalize by the total issuance amount in the last 3 or 12 months, given that newly issued MBS are often forward-sold through the TBA market (Fuster, Lucca, and Vickery, 2021). As reported in Table 5, the regression coefficients are quantitatively small and statistically insignificant, indicating that Fannie Mae and Freddie Mac MBS are indeed quite similarly likely to be delivered to settle TBA contracts after the UMBS implementation.

Specified pool trading. Third, we examine the potential adverse effects directly—whether allowing Freddie Mac MBS to be delivered into the same TBA contract as Fannie Mae MBS would drive trade of the latter to the SP market, or vice versa. We run difference-in-difference regressions of the ratio of SP trading volume to outstanding balance and to

Table 6: **Post-UMBS SP Trading**

	SP Volume/Outstanding Balance	SP Volume/Issuance
Fannie Mae	-0.00	-14.74
	(0.01)	(10.41)
Post-UMBS	0.05	-13.58
	(0.04)	(10.20)
Fannie Mae×Post-UMBS	-0.01	15.67
	(0.02)	(10.23)
Observations	471	433
Cohort FE	X	X

This table presents the results of difference-in-difference regressions of the ratio of SP trading volume to outstanding balance (in the first column) and to issuance amount (in the second column), respectively, on a dummy for post-UMBS period, a dummy for Fannie Mae, and its interaction term, controlling for moneyness cohort FE and time series factors. The sample period is from July 2018 to February 2020.

issuance amount, respectively, on a dummy for post-UMBS period, a dummy for Fannie Mae, and its interaction term, controlling for moneyness cohort FE. The coefficient on the interaction term captures whether trading of Fannie Mae MBS migrates into SP market relative to trading of Freddie Mac MBS. As reported in Table 6, the coefficient is small and insignificant, showing that UMBS implementation did not cause a disproportionate increase in SP trading of Fannie Mae MBS relative to Freddie Mac MBS.

V.C Comparison to Ginnie Mae

Given these successful efforts to limit asset heterogeneity, as documented above, we may expect that liquidity should improve not just for Freddie Mac but also for Fannie Mae as a result of UMBS, because of the liquidity externality effect; see Hypothesis 4 (ii). To test this hypothesis, we conduct difference-in-difference analyses using Ginnie Mae MBS as a comparison group, given that Ginnie Mae was not part of the Single Security Initiative.

Column (1) in Panel A of Table 7 reports the results from regressing the Fannie Mae–Ginnie Mae difference in TBA trading volume on three time dummies representing the UMBS transition period (see Table 4), while column (2) reports the result for Freddie Mac–Ginnie Mae difference. Because the UMBS implementation results in full convergence between Fannie Mae and Freddie Mac TBA trading, we also examine the difference between the sum of Fannie Mae and Freddie Mac TBA trading volume and Ginnie Mae TBA trading volume, denoted as "GSE–Ginnie", as reported in column (3). We observe that relative to Ginnie Mae, Freddie Mac TBA trading volume increased significantly throughout the transition period; importantly, Fannie Mae TBA trading volume is also on the upswing, especially during the period from July 2018 to February 2019. Together, the GSE TBA trading volume increased significantly after the UMBS implementation. We find similar results for turnover regressions reported in columns (4)-(6).

Turning to trading cost, price, and OAS, Panel B of Table 7 reports the results of regressions of the Fannie Mae–Ginnie Mae and Freddie Mac–Ginnie Mae differences in these three measures, respectively. We include not only the three time dummies for the transition period but also the time dummy for the post-UMBS period (for which trading cost, price, and OAS for UMBS TBAs are used for both Fannie Mae and Freddie Mac). Relative to Ginnie Mae, prices of Freddie Mac MBS increased and OAS decreased significantly both in the transition period and after the UMBS implementation, whereas the changes in price and OAS of Fannie Mae MBS are small and not significant. Changes in trading cost of both Fannie Mae and Freddie Mac MBS are also small and insignificant.

Finally, columns (7)-(8) in Panel A of Table 7 reports the result of regressions of the Fannie Mae–Ginnie Mae and Freddie Mac–Ginnie Me differences in monthly issuance. We observe significant increases in issuance for both Freddie Mac and Fannie Mae MBS relative to Ginnie Mae. The increases are quantitatively similar in the transition period but larger for Freddie Mac than for Fannie Mae. This is consistent with the insignificant change of the Fannie Mae–Freddie Mac gap in issuance amount in the transition period and its significance drop after the UMBS implementation, as reported in the last column of Table 4.

We are careful not to over-interpret these results, because Ginnie Mae MBS are not an ideal control group given the differences in security design and borrower population compared to MBS issued by the GSEs. One of the most notable confounding events during

Table 7: Comparison with Ginnie Mae MBS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Fannie-Ginnie	Freddie-Ginnie	GSE-Ginnie	Fannie-Ginnie	Freddie-Ginnie	GSE-Ginnie	Fannie-Ginnie	Freddie-Ginnie
	A: Trading Volume and Issuance							
	Log(Volume)			Log(Volume/Balance)			Log(Issuance)	
2016/07 to 2017/06	-0.05	0.20***	-0.02	-0.01	0.20***	0.00	0.06**	0.10**
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.03)	(0.04)
2017/07 to 2018/06	-0.01	0.14**	0.01	0.04	0.13**	0.03	0.20***	0.22***
	(0.04)	(0.06)	(0.04)	(0.05)	(0.06)	(0.04)	(0.04)	(0.05)
2018/07 to 2019/02	0.08**	0.40***	0.12***	0.12***	0.36***	0.13***	0.33***	0.36***
	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.03)
2019/03 to 2020/02			-0.01			-0.03	0.24***	0.39***
			(0.06)			(0.06)	(0.04)	(0.03)
Observations	44	44	56	44	44	56	56	56
	B: Price Gap, OAS, and Transaction Cost							
	Price Gap (% of par)			OAS (bp)			RTC	
2016/07 to 2017/06	-0.264*	-0.047		6.927**	2.228		0.000	0.018
	(0.137)	(0.127)		(3.427)	(3.192)		(0.013)	(0.014)
2017/07 to 2018/06	0.150	0.403**		0.220	-4.883		-0.000	0.014
	(0.178)	(0.174)		(3.907)	(3.730)		(0.013)	(0.014)
2018/07 to 2019/02	0.003	0.354***		0.067	-7.021***		-0.004	-0.004
	(0.127)	(0.109)		(2.831)	(2.443)		(0.010)	(0.011)
2019/03 to 2020/02	-0.108	0.229**		6.712**	-1.677		-0.013	-0.001
	(0.115)	(0.103)		(3.073)	(3.002)		(0.010)	(0.010)
Observations	440	440		440	440		5348	4912
Cohort FEs	X	X		X	X		X	X
Cohort x CPR Diff	X	X		X	X			
Controls	X	X		X	X		X	X

Columns (1)-(2) in Panel A report results of monthly time series regressions of the Fannie Mae–Ginnie Mae and Freddie Mac–Ginnie Mae gap in TBA trading volume on three time dummies for the transition period, while column (3) reports the result of monthly time series regressions of GSE (sum of Fannie Mae and Freddie Mac)–Ginnie Mae difference in TBA trading volume on the three time dummies for the transition period and a time dummy for post-UMBS period. Columns (4)-(6) in Panel A report results similar to those in columns (1)-(3) but for turnover (TBA trading volume/outstanding balance). Columns (7)-(8) in Panel A report results of monthly time series regressions of the Fannie Mae–Ginnie Mae and Freddie Mac–Ginnie Mae gap in issuance amount on three time dummies for the transition period and a time dummy for post-UMBS period. Panel reports results from regressing Fannie–Ginnie and Freddie-Ginnie differences in round-trip trading cost, price, and OAS at the time×cohort level on the three time dummies for the transition period and a time dummy for post-UMBS period, controlling for moneyness cohort FE, its interaction with the Fannie Mae–Freddie Mac difference in prepayment rate forecast and time series variables including the Baa-Aaa corporate bond yield spread and agency debt-swap spread. The sample period is July 2015 to February 2020. Standard errors clustered by month are in parentheses. Significant at *p<0.10, **p<0.05, ***p<0.01.

this sample period is the introduction of liquidity coverage ratio, which favors Ginnie Mae MBS relative to GSE MBS (Roberts, Sarkar, and Shachar, 2018; Gete and Reher, 2020; He and Song, 2020). This may be the reason why we observe an increase in OAS and decline in prices for Fannie Mae relative to Ginnie Mae during the 2016-17 period. However, we at least find no evidence that the Single Security Initiative had negative effects on market quality for Fannie Mae MBS, and on some dimensions there is an improvement in Fannie Mae MBS liquidity, consistent with the benefits of liquidity network externalities. Quantitatively these effects are likely to be modest, however, given that Fannie Mae already made up the lion's share of TBA trading even prior to the UMBS reform.

VI Conclusion

We provide one of the first empirical analyses of market fragmentation in U.S. fixed-income markets. Guided by theories of endogenous market concentration and liquidity, we show that both secondary market liquidity and primary market agency MBS activity were highly concentrated in the Fannie Mae segment of the TBA market, resulting in a liquidity premium for Fannie Mae securities relative to Freddie Mac. We further show that the market consolidation reform engineered by the Single Security Initiative improved liquidity of Freddie Mac MBS together without negative consequences, and in fact perhaps some improvement in liquidity for Fannie Mae MBS. Actions taken to align fundamentals of the MBS issued by these two agencies suppressed asset heterogeneity and its potential adverse effects, which likely played an important role in consolidating the fragmented Freddie Mac and Fannie Mae TBA segments into a single market.

As well as expanding the existing equity-focused analyses of market fragmentation and liquidity to fixed-income markets, we provide novel evidence on the importance of asset heterogeneity for market liquidity. As highlighted in the survey by Bessembinder, Spatt, and Venkataraman (2019), asset heterogeneity and market fragmentation are key features of the microstructure of fixed-income markets. Our analyses provide stylized facts for potential future theoretical developments of asset heterogeneity and market liquidity. Moreover, our comprehensive evaluation of the consequences of the Single Security Initiative, which is a historic market consolidation "experiment", has significant broad implications for potential reforms in other markets such as those for corporate bonds, municipal bonds, and so on.

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Appendix

A Historical Development of the Agency MBS Market

Fannie Mae was established by the U.S. Congress in 1938, as part of the policy response to the severe wave of mortgage defaults and foreclosures during the Great Depression. Fannie Mae was partially privatized in 1968 and authorized to purchase conventional loans in 1970 (the other part of it became the current Ginnie Mae). Freddie Mac was also established by the federal government in 1970 to compete with Fannie Mae and facilitate a robust and efficient secondary mortgage market. Since that time, Fannie Mae always had a larger market share of mortgage loans in terms of purchases and total loans compared to its competitor.

Fannie Mae was not the first agency to issue MBS — Ginnie Mae guaranteed the first mortgage pass-through security of an approved lender in 1968, and Freddie Mac issued its first mortgage pass-through security in 1971, while Fannie Mae began issuing MBS only in 1981 (see Frame and White (2005), McConnell and Buser (2011) and Frame, Fuster, Tracy, and Vickery (2015)). However, as a result of its larger size, Fannie Mae eventually became the dominant player in the agency MBS market by the 1990s. As shown in Frame and White (2005) (Table 1, page 162), Fannie Mae had about $510 billion of outstanding MBS in 1995, compared to $460 billion for Freddie Mac; this gap then widened sharply in the following years, to $1.3 trillion for Fannie Mae compared to $770 billion for Freddie Mac as of 2003.

Moreover, prepayment rates of Freddie Mac MBS were historically faster than those of Fannie Mae when mortgages were in the money (Goodman and Ranieri, 2014). This resulted in a price discount for Freddie Mac MBS. However, Freddie Mac and Fannie Mae MBS prepayment rates have substantially converged in recent years as shown in the body of this paper.

B Measuring loan-level price adjustments (LLPAs)

Our procedure for adjusting guarantee fees for the effect of LLPAs is as follows:

1. We obtain annual LLPA pricing matrices published by Fannie Mae. These matrices are essentially lookup tables that report the applicable LLPA for different bins of loan characteristics: e.g., combinations of credit score, loan-to-value (LTV) and loan type

(purchase vs refinancing).[14]

2. From eMBS we draw loan-level information on the characteristics of each mortgage securitized by Fannie Mae and Freddie Mac from 2013 onwards. We then classify each loan into an LLPA bin based on its characteristics, and merge in the relevant LLPA from the pricing matrix described in step 1.

3. We collapse the resulting loan-level data by agency and quarter (based on the first payment date of the loan) to obtain an overall weighted average LLPA. We then convert this LLPA to an equivalent periodic fee assuming an approximate price-yield multiplier of 5 consistent with the average estimates of Fuster, Lo, and Willen (2017). This is because guarantee fees are reported by the GSEs on a periodic basis (as described by the GSEs in their 10-Qs, up-front fees are amortized over the expected life of the loan for this calculation).

4. We then construct an LLPA-adjusted guarantee fee for each agency and quarter by subtracting this periodic-equivalent LLPA from the new-purchase guarantee fee by agency and quarter.

C Measuring UMBS TBA Settlements

The Federal Reserve's MBS purchases are executed exclusively through the TBA market. Therefore the composition of MBS pools delivered to the Fed can be used to infer which securities are the cheapest-to-deliver MBS pools used to settle TBA trades. We conduct such an analysis for the UMBS TBA contracts into which either Fannie Mae or Freddie Mac MBS can be delivered. We infer Fed UMBS deliveries using the following procedure:

1. Save a CUSIP-level dataset consisting of Fed agency MBS holdings data in the first week of each calendar month (the Fed reports its portfolio composition at a weekly frequency). Because TBA settlements occur monthly, these values reflect the principal balance of holdings at the end of the prior month, after accounting for new pools received in that month and net of principal paydowns from borrowers paid out to investors (which are received late in the month but prior to the end of the month).

[14] We adjust the applicable pricing matrices for the fact that refinancings under the Home Affordable Refinancing Program (HARP) had a lower LLPA of 75bp. We identify refinancings as HARP loans if they were originated during the period of the HARP program and had a loan-to-value exceeding the maximum reported in the relevant Fannie Mae pricing matrix. We cross-validate this measure by confirming that the quantity of purchase loans exceeding this threshold is low, while the quantity of refinancings is high and corresponds to the period of peak HARP activity.

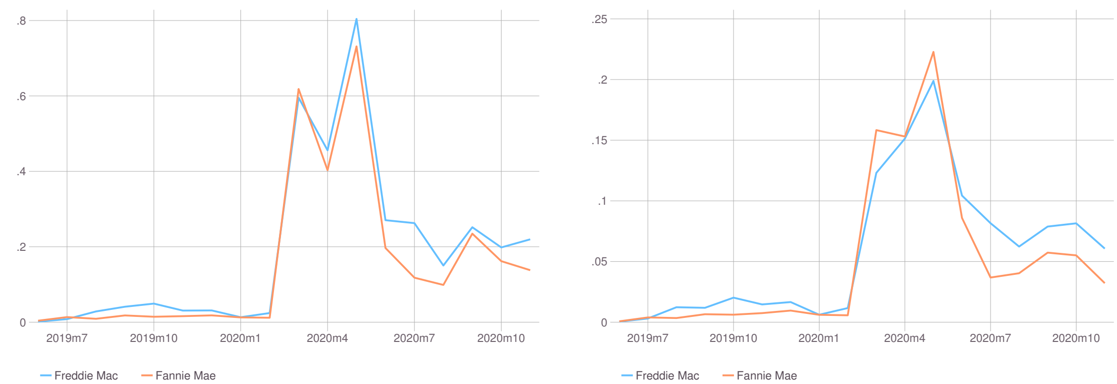

Figure A1: **Settlements of UMBS TBA Contracts Purchased by the Federal Reserve**

This figure reports monthly time series of the amount of Fannie Mae and Freddie Mac MBS, respectively, delivered to settle the UMBS TBA contracts purchased by the Federal Reserve. The left panel normalizes the delivery amount by the cumulative issuance amount within the last three months for Fannie Mae and Freddie Mac MBS respectively, while the right panel normalizes by the cumulative issuance amount within the last 12 months. The sample period is from June 2019 to December 2020.

2. Drop all holdings reflecting the Fed's resecuritizations of level 1 MBS pools. The Fed periodically aggregates its holdings into a smaller number of level 2 resecuritizations; these transactions involve the creation of new CUSIPs but are not asset purchases.

3. Merge the data by CUSIP x month to eMBS data on the survival factor ($s_{p,t}$) of pool p at time t: this is the fraction of the original pool balance not yet paid down.

4. Compute purchases as the difference between actual and predicted balance, where predicted balance is calculated as $balance_{t-1} \times s_{p,t}/s_{p,t-1}$.

In addition to the results presented in Table 5, we plot time series of total Fannie Mae and Freddie Mac UMBS TBA settlements in Figure A1. As we can see, the two series move closely together with Fannie Mae settlements only slightly below Freddie Mac (scaled by the stock of outstanding bonds). Most notably, the two series move very similarly during the 2020 refinancing wave, when prepayment spiked and any difference in prepayment characteristics between Fannie Mae and Freddie Mac would be likely to be significantly amplified.

D Additional Results and Robustness Checks

Table A1: **Gap in Bid-Ask Spread**

	Fannie-Freddie		Fannie-Ginnie	Freddie-Ginnie
Fannie-Freddie Diff	-0.039***			
	(0.003)			
2016/07 to 2017/06		0.003***	0.040***	0.024***
		(0.001)	(0.008)	(0.007)
2017/07 to 2018/06		0.004***	0.047***	0.023***
		(0.001)	(0.008)	(0.006)
2018/07 to 2019/02		0.001	0.033***	0.016***
		(0.001)	(0.006)	(0.004)
2019/03 to 2020/02			0.023***	0.022***
			(0.006)	(0.006)
Freddie Mean	.091			
Observations	7747	4722	6386	4832
Cohort FEs		X	X	X
Cohort x CPR Diff Interaction			X	X
Controls		X	X	X

This table reports transaction results using the bid-ask spread from Tradeweb as an alternative transaction cost measure. The first column repeats the third column of Table 2. The second column repeats the third column of Table 4. The last two columns repeat columns (7) and (8) in the bottom panel of Table 7. Standard errors are clustered at the daily level. * is p <0.10, ** is p<0.05, *** is p<0.01.

Table A2: **Fannie Mae–Freddie Mac Gap in Characteristics**

	CPR		Credit Score			LTV			Loan Size		
	Average	80th perc	Average	20th perc	80th perc	Average	20th perc	80th perc	Average	20th perc	80th perc
						A: Outstanding					
Fannie-Freddie Gap	-0.16	-0.14	2.71***	0.64	5.42***	-0.75***	-1.07***	-0.46	6056.34***	2457.21	9032.25***
	(0.15)	(0.15)	(0.88)	(0.89)	(0.95)	(0.28)	(0.32)	(0.33)	(1880.70)	(1593.80)	(2648.05)
Mean (Freddie Mac)	1.628	2.284	744.2	737.4	753.4	74.81	70.37	78.3	212902	170969	256486
Observations	475	475	474	474	474	474	474	474	473	473	473
						B: New Issuance					
Fannie-Freddie Gap	-0.02	-0.06	-0.52	-1.89***	0.76***	-0.33**	-0.95***	0.07	4901.26**	1806.26	8396.35***
	(0.02)	(0.08)	(0.40)	(0.46)	(0.27)	(0.16)	(0.18)	(0.19)	(1977.63)	(2018.40)	(2692.15)
Mean (Freddie Mac)	1.524	2.295	746.6	739	757.5	73.7	69.42	77.17	219767	174139	266116
Observations	452	452	452	452	452	452	452	452	451	451	451

This table reports results of regressing the Fannie-Freddie gap in bond characteristics on a constant term. The first two columns are on CPR. The next three columns are on the average credit score of borrowers. The next three columns are on the original LTV. The last three columns are on the original loan size. The sample period for the top panel is January 1998 to June 2016. The sample period for the bottom panel is May 2011 to June 2016. Standard errors are clustered at the monthly level. Data used in this table is from eMBS. * is $p < 0.10$, ** is $p < 0.05$, *** is $p < 0.01$.