Defragmenting Markets: Evidence from Agency MBS *

Haoyang Liu† Zhaogang Song‡ James Vickery§

December 30, 2021

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 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.

Keywords: Liquidity, MBS, Single Security Initiative, TBA, UMBS

JEL classification: G12, G18, G21, E58

*We are grateful to Natalie Newton, Dick Oosthuizen, David Rubio and Dean Parker for outstanding research assistance. For helpful comments, we thank Alina Arefeva, Andy Davidson, Yongheng Deng, Laurie Goodman, Brian Greene, Wenqian Huang (discussant), Boyan Jovanovic (discussant), Sanket Korgaonkar (discussant), Jeffery Levine, Matthew Milroy, Adi Sunderam, Milena Wittwer, and Dayin Zhang, as well as seminar participants at the Swiss National Bank Conference on the Microstructure of Financial Markets, Wisconsin Real Estate Research Conference, the 2021 AREUEA National Conference, University of Technology Sydney, Federal Reserve "Week After" Conference on Financial Markets and Institutions, and the Australian Finance and Banking Conference. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York, the Federal Reserve Bank of Philadelphia, or the Federal Reserve System.

†Federal Reserve Bank of New York, E-mail: haoyang.liu@ny.frb.org.

‡The Johns Hopkins Carey Business School, E-mail: zsong8@jhu.edu.

§Federal Reserve Bank of Philadelphia, E-mail: james.vickery@phil.frb.org.

1 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 (Vickery and Wright, 2011; Gao, Schultz, and Song, 2017). 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, (2) consider the effect of asset heterogeneity, and (3) study an unusual large-scale market design experiment that significantly altered the degree of fragmentation.

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 segment. This is consistent with theories of endogenous market concentration, which predict market activities 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

[1] $8.4 trillion of agency MBS was outstanding as of 2020:Q4 (source: Securities Industry and Financial Markets Association, SIFMA), smaller than $21.0 trillion of Treasury securities but comparable to $10.6 trillion of corporate bonds and higher than $3.9 and $1.5 trillion of municipal bonds and asset-backed securities respectively. Around 90% of agency MBS is backed by 1-4 family residential mortgages; the remainder comprises multifamily and other commercial mortgages (Fuster, Lucca, and Vickery, 2021).

theories, which generally consider assets that are ex-ante identical, are silent as to which segment will arise as the focal venue. 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. Fannie Mae's dominance in the MBS market reflected the fact that it is older and historically larger than Freddie Mac (see Appendix).

We use four measures to quantify the concentration in the TBA market: trading volume scaled by outstanding balance, round-trip trading cost, prices, and yields.[2] Agency MBS are typically issued with coupon rates in 50 basis point (bp) increments (e.g, 4.5%, 4.0%, 3.5%, etc), and TBA trading occurs at a coupon-cohort level (e.g., Fannie Mae 30-year MBS with a 4% coupon rate). At any point in time there are MBS with different coupons outstanding. We measure trading volume in aggregate by summing across coupon cohorts, but analyze trading cost, price, and yield at the coupon-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 a firm timetable for the Single Security Initiative was set).[3] Trading cost is also lower for Fannie Mae, although the difference is small given that the TBA market overall is extremely liquid (our estimate of Freddie Mac TBA trading cost is only 2 bp, consistent with Bessembinder, Maxwell, and Venkataraman (2013) and Gao, Schultz, and Song (2017)). Further, Fannie Mae MBS command a liquidity premium over Freddie Mac, of about 17 cents per $100 face value in price and about 4 bp in yield. These estimates control for prepayment speed differences, indicating they are due to liquidity effects rather than prepayment characteristics. As further evidence, we show that there is still 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 the concentration in the primary market. First, we show that the monthly security issuance of Fannie Mae MBS was about 50% higher than for Freddie Mac in the period prior to the Single Security Initiative. Second, using data from GSE 10-

[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 expected return 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.

K filings we also show that Freddie Mac's guarantee fee (G-fee) income was consistently 5-10 bp lower than Fannie Mae.[4] This is consistent with Freddie Mac's known practice of discounting G-fees for its less liquid MBS in order to remain competitive with Fannie Mae. In the economic framework of endogenous market concentration and liquidity, Freddie Mac's lower G-fee income can be viewed as a measure of 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 with their public conservatorships.

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 then, 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 (see below).

We first examine whether market consolidation led to a convergence in liquidity between Fannie Mae and Freddie Mac. By construction, TBA trading volume, cost, and price differences between the two GSEs 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 yields fell by up to 7 bps (almost all of the prior difference). We find no change in the trading cost gap, however, which was already small prior to the transition period.

Further, we find that the effects of TBA trading consolidation flowed through to the primary market. In particular, the gap in MBS issuance between Fannie Mae and Freddie Mac shrank, and the difference in guarantee fees between the two GSEs entirely disappeared as Freddie Mac was able to remove G-fee discounts. These changes in the primary market materialized only after the UMBS implementation.

A network externality view of liquidity would predict that consolidation not just results in convergence between Fannie Mae and Freddie Mac, but also leads to an absolute

[4] Goodman and Ranieri (2014) provides a back-of-envelope estimate that Freddie Mac lost as much as $1bn per year in fee income due to discounts compensating for the illiquidity of its MBS relative to Fannie Mae.

improvement in liquidity for both GSEs. However, there was also a risk of unintended adverse effects. In particular, the TBA contract trades on a cheapest-to-deliver basis; as a consequence, higher-value MBS trade on an individual basis in the less liquid specified pool (SP) market. Consolidating the Fannie Mae and Freddie Mac TBA segments could enlarge asset heterogeneity within each TBA cohort, diverting more trade to the SP market and diminishing overall market liquidity (Li and Song, 2020). As mentioned above, 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 Federal Reserve 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. Amid the preserved homogeneity, Fannie Mae liquidity should also improve, benefiting from the network externalities associated with TBA market consolidation. We indeed find supportive evidence 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 con-

servative (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).[5] 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.[6] 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

[5] Theoretical models of 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) considers heterogeneous assets, more in line with the features of the TBA market.

[6] 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.

and Song (2020) study variation in agency MBS safety and liquidity premia.[7] We differ by examining liquidity premium differentials across agencies associated with market fragmentation and consolidation.

2 Institutional Background, Economic Framework, and Data

In this section, we first introduce the institutional background of the agency MBS market briefly, focusing on the fragmentation and consolidation of Fannie Mae and Freddie Mac MBS trading. We then outline the economic framework and describe the data sets used.

2.1 Institutional Background

Agency MBS market. The agency MBS market is one of the largest and most active fixed-income markets in the world. According to the Urban Institute and SIFMA, as of 2020 Q4, it finances 62% of U.S. home mortgage debt,[8] while its average daily trading volume is more than $200bn. Guaranteed by Fannie Mae, Freddie Mac, and Ginnie Mae, agency MBS are effectively default-free; yet, they are subject to uncertainty on the timing of cash flows, known as prepayment risk, because U.S. mortgage borrowers can prepay mortgage loans without penalty.

Agency MBS are traded either through a SP trade where counterparties transact a particular security, or a TBA forward trade where any MBS within an eligible set can be delivered to the buyer.[9] A TBA contract specifies, for example, a Fannie Mae 30-year fixed-rate MBS with a 4% security coupon rate, and the particular MBS that a seller delivers needs to be identified only two days before the settlement day.[10] At any given

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

[8] The remaining consists of 28.9% of unsecuritized first liens, 4% of home equity loans, and 3.7% of private-label MBSs. The share of private-label MBSs reached a peak right before the 2008 crisis, about 40% of the total mortgage debt, but has shrunk dramatically and stayed at low levels since then.

[9] 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.)

[10] TBA contracts have only one settlement date per month set by SIFMA (e.g., for 30-year Fannie Mae MBS,

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 "homogeneous" cohort, TBA trading is remarkably liquid and incurs low transaction costs of only a few basis points, whereas SP trading incurs high costs of 60-80 basis points (Bessembinder, Maxwell, and Venkataraman, 2013; Gao, Schultz, and Song, 2017). As a forward contract, TBA trade is also used for risk hedging by both mortgage lenders and MBS investors. Hence, TBA trading is significantly more active than SP trading, accounting for more than 90% of total agency MBS trading volume.

Though being liquid and active, TBA contract features a cheapest-to-deliver issue like Treasury futures because the price is set without specifying which MBS would be ultimately delivered. In consequence, relatively high-value MBS are often traded in the SP market.[11] As shown in Fusari, Li, Liu, and Song (2021), an enlarging MBS heterogeneity would cause an increasing share of MBS to be traded in SP market.

Fragmentation and consolidation of GSE MBS. Different from Ginnie Mae that issues MBS backed by mortgage loans insured by two US government entities (the Federal Housing Administration and the Veterans Administration), Fannie Mae and Freddie Mac issue MBS backed by mortgage loans of standard U.S. households or conventional loans, which we focus on. Both Fannie Mae and Freddie Mac are private but government-sponsored enterprises that have been in public conservatorship since September 2008.[12] Therefore, Fannie Mae and Freddie Mac MBS are fairly homogeneous in terms of loan characteristics and scope of government-backing.

Notwithstanding relatively homogeneous fundamentals, market activities of Fannie Mae and Freddie Mac MBS differ largely, with both primary market issuance and secondary market trading historically concentrated in the Fannie Mae segment. This concentration has been long recognized in practice and concerning policy makers deeply. For example, Freddie Mac was often forced to discount its guarantee fees to mortgage

settlement day is typically around the 12th or 13th of the month).

[11] An, Li, and Song (2021b) estimate that around half of newly-issued TBA-eligible MBS are first sold through SP trading. Moreover, the hedging-motivated TBA contracts are usually reversed before settlements, resulting in no MBS exchanging hands.

[12] Ginnie Mae is a government agency within the Department of Housing and Urban Development that provides investor guarantees on MBS backed by federally insured mortgages. For more background on Fannie Mae and Freddie Mac, see Acharya, Richardson, Nieuwerburgh, and Wright (2011) or Frame, Fuster, Tracy, and Vickery (2015).

sellers to compensate for the lower liquidity of its MBS:

"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, 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). The FHFA then confirmed its commitment to a single security in its 2014 strategic plan, and issued a Request for Input that outlines the specific design on August 12, 2014, (FHFA, 2014). The final design was announced on July 11, 2016.

The consolidation may increase the asset heterogeneity within a TBA cohort and drive more trade to the illiquid SP market, as discussed above. The FHFA has been aware of this potential adverse effect and taken important steps to deal with it since the beginning. In particular, together with the 2012 Strategic Plan, the FHFA announced an initiative to construct a Common Securitization Platform to replace Fannie Mae and Freddie Mac's separate proprietary systems. As it put, "transitioning to a single platform was also thought to maximize economies of scale and enhance MBS uniformity and liquidity."[13] The GSEs then completed the operational and product on readiness of the Common Securitization Platform on November 21, 2016, known as "Release 1." On March 18, 2018, the FHFA announced that issuance of MBS through the Common Securitization Platform, also called New Uniform Mortgage-Backed Security (UMBS), would begin in June 2019, known as "Release 2."

Issuance of UMBS 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.[14] Because MBS can be traded on the TBA market up to three months

[13] Given that the single security initiate keep Fannie Mae and Freddie Mac as two competitive entities rather than merging them into a monopoly, the competitiveness is unlikely to be diminished.

[14] 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

before issuance, UMBS forward trading began on March 4 2019. Post-UMBS, Fannie Mae and Freddie Mac TBA trading are completely consolidated: a TBA seller can deliver MBS issued by either agency, or a combination, when the forward contract is settled.

2.2 Economic Framework and Testing Hypotheses

In this section, we develop testing hypotheses framed under 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 because of liquidity network externality.

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. Fannie Mae is an older and larger agency of mortgage loans than Freddie Mac from the beginning (see Appendix A for historical details). In consequence, market liquidity became concentrated in the Fannie Mae segment with an endogenous liquidity premium relative to Freddie Mac. These predictions are summarized in the following hypothesis:

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

Although the above models focus on secondary market trading, the same mechanism of network externality can also apply to the primary market. In fact, as detailed in Appendix A, Fannie Mae's dominance took place first in the mortgage loan market because of its historical prominence and then extended to the secondary market. There is also likely a feedback channel between secondary and primary markets: greater secondary market liquidity would support higher primary market share and securitization fee income, which strengthen secondary market liquidity. These predictions are summarized

investors, rather than the 45 day delay used for legacy Freddie Mac pools). UMBS disclosure rules generally follow those previously set by Freddie Mac.

in the following hypothesis:

Hypothesis 2 ***[Effects of fragmentation on primary market]*** *Prior to UMBS, Fannie Mae MBS have higher issuance and than Freddie Mac MBS, and Fannie Mae acquires higher guarantee fees than Freddie Mac.*

Next, we consider effects of the TBA trading consolidation of Fannie Mae and Freddie MBS. By construction, consolidation would result in full convergence in TBA liquidity and price *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 hypotheses above, we consider the convergence in both primary and secondary markets:

Hypothesis 3 ***[Market consolidation and convergence]*** *The Single Security Initiative would diminish the differential of Fannie Mae and Freddie Mac MBS in secondary market liquidity, liquidity premium, primary market issuance, and agency G-fee; the diminishing effect can start prior to the final implementation.*

A convergence of Fannie Mae and Freddie Mac MBS liquidity does not necessarily mean liquidity improvement for both Fannie Mae and Freddie Mac MBS. This would be true based on network externality of liquidity, *if* no significant adverse effects arise from market consolidation. However, potential adverse effects do exist because of asset heterogeneity. In particular, TBA is traded at a cheapest-to-deliver price for different MBS, so enlarging asset heterogeneity associated with market consolidation could drive relatively high-value MBS to trade on in less liquid SP market. This would hurt liquidity of high-value MBS–especially Fannie Mae MBS that historically had slightly more favorable prepayment characteristics and higher values than Freddie Mac MBS on average—and even market liquidity in aggregate (Li and Song, 2020). 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 preventing the adverse effects described above. If these steps were successful in homogenizing the Fannie Mae and Freddie Mac MBS, we would have

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 of Fannie Mae and Freddie MBS both improve.

2.3 Data

We use three main data sets: (1) eMBS, which provides data on MBS issuance, outstanding balance, realized prepayment rates, and TBA eligibility; (2) the TRACE data of agency MBS transactions;[15] (3) J.P. Morgan Markets, which provides data on MBS prices, yields, and prepayment forecasts. Our maximum sample period is from January 1998 to February 2020, but the specific sample of different measures varies according to data availability. Details of the main measures we use are provided as follows.

MBS trading volume and cost. Given that TBA contracts settle in a monthly cycle, we measure their monthly total trading volume, based on the TRACE data. We focus on the most active front-month TBA contracts for 30-year Fannie Mae, Freddie Mac and Ginnie Mae MBS.[16] To measure trading cost, we use the standard round-trip trading cost computed as the difference between dealers' selling prices to customers and buying prices from customers (Bessembinder, Maxwell, and Venkataraman (2013); Friewald, Jankowitsch, and Subrahmanyam (2017); Gao, Schultz, and Song (2017)). We also compute the monthly total SP trading volume by summing over different individual SP trades. These measures of MBS trading are available from May 2011 onward, when TRACE began collecting data of agency MBS transactions.

MBS price and yield. We obtain monthly series of prices of front-month TBA contracts of 30-year Fannie Mae, Freddie Mac and Ginnie Mae MBS. These price series are from J.P. Morgan and available from January 1998 onward.[17] We further obtain the option-adjusted spread (OAS) calculated 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

[15] We use the supervisory version of TRACE, which does not truncate trade sizes and includes individual dealer identifiers.

[16] We keep only regular good-delivery outright TBA trades with standard fixed coupon payments and without stipulations. Hence, trades involving stipulated TBA contracts and dollar rolls, those not qualified for good delivery, and those with quarter or non-standard coupon rates are excluded.

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

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 contains non-interest-rate-driven prepayment risk premium, an issue we shall address later).[18] We use OAS series based on the Libor term structure (results remain similar using OAS relative to the Treasury term structure).

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.

These measures—trading volume, round-trip trading cost, price, OAS, issuance, and outstanding balance—are all available at the coupon-stack level (which are in increments of 50 bps, as discussed in the Introduction). Similar to the literature (Diep, Eisfeldt, and Richardson, 2021), we group coupon stacks or cohorts based on moneyness (defined as the difference between the coupon rate and the "current coupon," which is the coupon rate for a synthetic TBA contract trading exactly at par and 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 ensure that we focus on actively traded MBS, we limit the sample to coupon stacks 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.

Table 1 provides a summary of the data sample and measures. Trading volume, outstanding balance and issuance are summed across Fannie Mae and Freddie Mac MBS, and price and OAS are computed as the average across the two agencies. As reported in the first row of the first three columns, the average monthly total TBA trading vol-

[18] 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. Following the standard market practice, we adjust Fannie Mae MBS prices by 2/32nds of a percentage point. This two-tick approximation of the value of payment timing difference (TBAs are traded in increments of a "tick," equal to 1/32nd of a percent) is likely a slight over-adjustment in our sample during which interest rates are at historically low levels. Hence, our estimate of the liquidity premium of Fannie Mae MBS relative to Freddie Mac MBS tends to be conservative. Moreover, the calculation of OAS accounts for the 10-day payment timing differential.

ume and issuance amount are about $1.08 trillion and 50.32 billion respectively, while the average aggregate outstanding balance is about $2.11 trillion. A breakdown into moneyness cohorts in the remaining rows show that market activities are indeed most active for coupon cohorts near par. In particular, the average TBA trading volume, issuance amount, and outstanding balance are about $300, $15, and $410 billions respectively for CC+1 and CC+2, but decrease to less than $100, $6, and $250 billions for coupon cohorts including and beyond CC-2 and CC+4.[19]

The fourth column of Table 1 provides the daily average of TBA round-trip trading cost (RTC) for each moneyness cohort. We find that TBA trading cost is quite low, less than one basis point for coupon cohorts near par and about 2-4 basis points even for in-the-money cohorts beyond CC+4, consistent with estimates in Bessembinder, Maxwell, and Venkataraman (2013) and Gao, Schultz, and Song (2017). Moreover, the fifth and sixth columns report the average TBA price and OAS. We observe that TBA price increases with moneyness, while OAS is higher than 20 bps for both out-of-the-money (CC-2) and in-the-money cohorts (beyond CC+3) but lower than 20 bps for cohorts relatively near par (CC-1, CC+1, and CC+2); see Boyarchenko, Fuster, and Lucca (2019), Diep, Eisfeldt, and Richardson (2021), and Fusari, Li, Liu, and Song (2021) for detailed analyses of across-coupon variations of MBS pricing.

Guarantee Fees. We collect quarterly data on guarantee fees from Fannie Mae and Freddie Mac's 10-Q and 10-K filings. 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. Up-front fees are amortized over the expected life of the mortgage. 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 of J.P. Morgan, which are based on its prepayment model and estimate of the actual set of pools likely to be delivered into TBA contracts. These monthly prepayment rates are annualized, often known as Conditional Prepayment Rate (CPR), which measure prepayments as a percentage of the current outstanding loan balance (a 10% CPR means that 10% of the current loan balance is to prepay over the next year).

[19]The relative 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.

Table 1: **Summary Statistics**

	Trading Volume ($bil)	Issuance ($bil)	Outstanding Balance ($bil)	RTC (cents per $100 par)	Price (% of par)	OAS (bp)
Aggregate						
Mean	1084.02	50.32	2111.53			
N	94	254	254			
CC-2						
Mean	31.85	5.68	182.85	.012	95.62	20.42
N	43	165	232	282	204	203
CC-1						
Mean	131.59	12.2	359.68	.005	98.7	17.81
N	75	219	244	858	226	225
CC+1						
Mean	296.61	15.79	434.64	.005	101.31	15.15
N	91	250	253	1639	235	235
CC+2						
Mean	367.36	14.55	413.87	.003	103.47	18.07
N	93	249	250	1923	215	215
CC+3						
Mean	201.43	5.39	356.11	.001	105.26	21.94
N	94	239	240	1785	191	191
CC+4						
Mean	73.36	1.3	236.88	.017	106.98	26.43
N	94	211	236	1227	161	161
CC+5						
Mean	27.73	.27	151.7	.036	108.78	28.38
N	93	131	215	692	131	131
CC+6						
Mean	13.18	.12	98.04	.041	110.16	30.67
N	83	54	191	372	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.

3 Effects of Market Fragmentation

In this section, we document the consequences of market fragmentation that existed prior to UMBS. We focus on the period before July 2016 when the FHFA sets a firm timetable and milestones for the Single Security Initiative as discussed in Section 2 (in the next section, we study improvements of market liquidity since July 2016).[20] Although the main consequence—MBS market activities were highly concentrated in Fannie Mae segment—was known anecdotally, our analysis is the first to comprehensively quantify the extent of concentration in both secondary and primary markets, to the best of our knowledge.

3.1 Secondary Market Trading

To first get an intuitive sense of the concentration of MBS trading in the Fannie Mae segment, the left panel of Figure 1 plots monthly time series of total TBA trading volume. We observe that TBA trading volume of Fannie Mae MBS is substantially larger than that of Freddie Mac MBS throughout the sample period. To provide a benchmark, the right panel plots month series of aggregate outstanding balance, which is also larger for Fannie Mae than Freddie Mac MBS. Importantly, the difference in TBA trading volume is much higher than the difference in outstanding balance, implying that the turnover—defined as TBA trading volume divided by outstanding balance—is higher for Fannie Mae than Freddie Mac MBS.

To provide quantitative estimates, the first two columns of Table 2 report the average (log) difference in TBA trading volume and turnover between Fannie Mae and Freddie Mac MBS, respectively. We observe that TBA trading volume of Fannie Mae MBS is 10.9 times ($\approx e^{2.44}$) larger than that of Freddie Mac MBS, while the turnover is 6.5 times ($\approx e^{1.94}$) larger. The third column then reports the average Fannie Mae–Freddie Mac gap in RTC. We observe that TBA trading of Fannie Mae MBS incurs a lower cost of about one basis point than TBA trading of Freddie Mac MBS, which incurs an average cost of about two basis points.

Next, we test whether Fannie Mae MBS commands a liquidity premium relative to Freddie Mac MBS. We run regressions of the Fannie Mae—Freddie Mac gap in price and OAS, $Price_{it}^{Gap}$ and OAS_{it}^{Gap} respectively for month t and moneyness cohort i, on

[20] Our main results are not particularly sensitive to the choice of cutoff date, as we show subsequently.

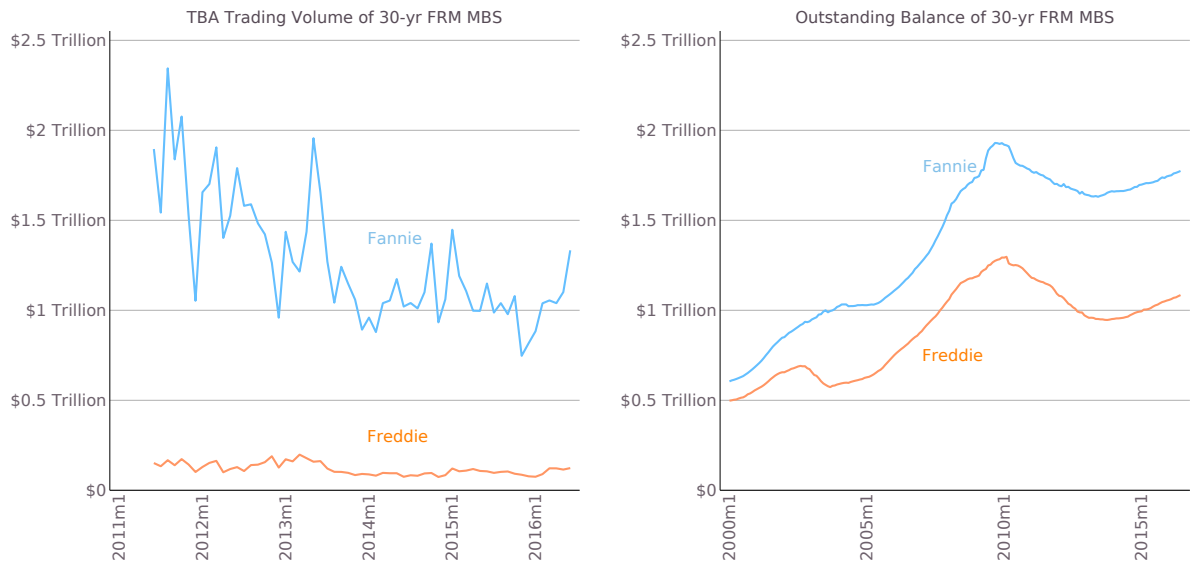

Figure 1: **TBA Trading Volume and Outstanding Balance**

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.

a constant. We include moneyness cohort fixed effect (FE) and its interaction with the difference in prepayment rate forecast ($I_{moneyness=i} \times \text{CPR difference}_{it}$) as controls, so the regression coefficients capture the average difference in TBA price and OAS beyond the average difference in prepayment speed. The prepayment rate forecasts are used here because they are measured for the set of MBS likely to be delivered into TBA contracts. As reported in the fourth and fifth columns of Table 2, the average price gap is +17 cents per $100 par value, while the average OAS gap is -3.9bp (these estimates are of consistent magnitudes, given that these MBS have an average option-adjusted duration of 4 years).

Although the estimates of Fannie Mae–Freddie Mac gap in price and OAS control for *average* prepayment speed difference, they may still reflect the difference in prepayment risk. To alleviate this concern, we look into coupon stacks. Specifically, Figure 2 reports the average Fannie-Freddie gap in price (left panel) and in OAS (right panel) estimated for each moneyness cohort separately, controlling for prepayment speed difference. We observe that the price gap and OAS gap are still around 20 cents and 5 bps, respectively,

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

	Log(Volume)	Log(Volume/Balance)	RTC	Price	OAS
Frequency	Monthly	Monthly	Daily	Monthly	Monthly
Gap	2.44***	1.94***	-0.011***	0.24***	-3.90***
	(0.04)	(0.04)	(0.002)	(0.029)	(0.38)
Mean (Freddie Mac)	90.39	.09	.020	102.50	21.44
Observations	124	124	13483	1232	1232
Cohort FE				X	X
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. Errors clustered by month are in parentheses. Significant at *p<0.10, **p<0.05, ***p<0.01.

for all coupon stacks close to par including CC-1, CC+1, and CC+2. Given that prepayment risk premia of such coupon stacks are negligible, as shown by Boyarchenko, Fuster, and Lucca (2019), our estimated price and OAS gap likely captures the liquidity difference rather than the difference in prepayment risk premium.

Overall, consistent with Hypothesis 1, results in this section show that Fannie Mae MBS have significantly larger trading volume and lower trading cost, and commands a liquidity premium, compared with Freddie Mac MBS.

3.2 Primary Market Issuance and Guarantee Fee

We then quantify the effects of market concentration on primary market issuance and G-fees Fannie Mae and Freddie Mac collect, as formulated in Hypothesis 2.

In particular, the left panel of Figure 3 provides bar charts of the average (across monthly series) total monthly issuance amount of Fannie Mae and Freddie Mac MBS.

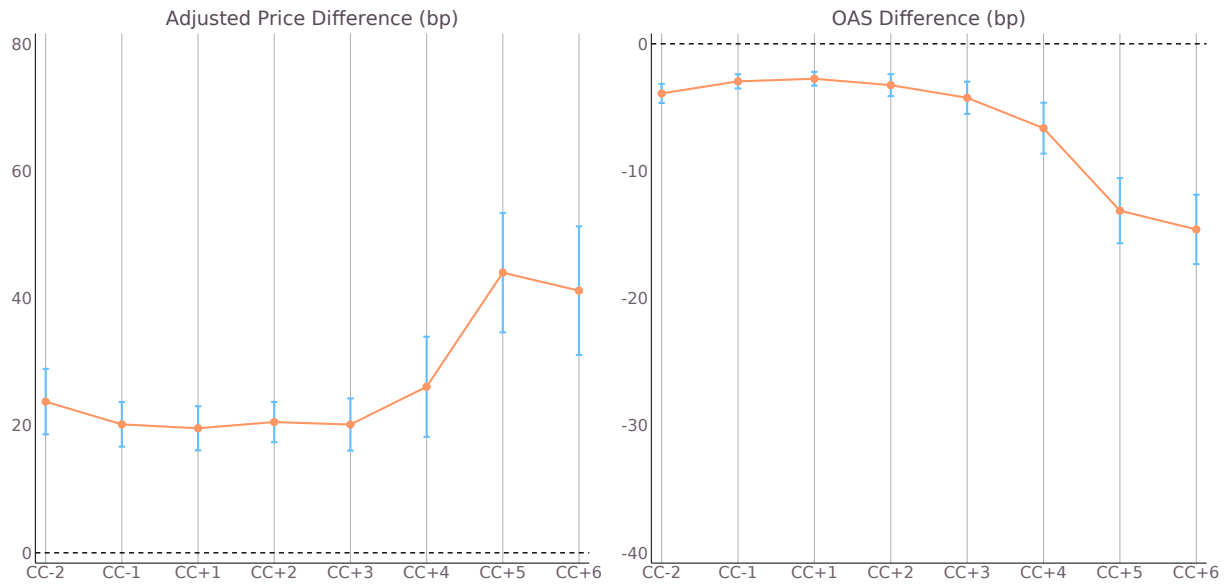

Figure 2: **Fannie–Freddie Gap in Price and OAS Across Coupon Cohorts**
This figure plots the average difference in price (left panel) and OAS (right panel) of Fannie Mae and Freddie Mac front-month TBA contracts for each moneyness cohort, obtained by monthly time series regressions at the moneyness 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.

We observe that Fannie Mae MBS have a larger issuance amount of around $32 billion, which is about 50 percent higher than that of Freddie Mac MBS about $20 billion.

Further, the right panel of Figure 3 provides bar charts of the average (across quarterly series) G-fees of Fannie Mae and Freddie Mac on new acquisitions and entire portfolios separately. We observe that Freddie Mac's net G-fee income is consistently 5-10 bp lower than Fannie Mae's on both new acquisitions and entire portfolios. To provide a back-of-envelop estimate of the dollar value, we consider 2016, just prior to UMBS implementation, when Freddie Mac had about $1.5tr in single-family MBS outstanding. A 5bp gap in annual G-fee income on this entire balance amounts to about a gap of $750 million per annum. This simple calculation is consistent with Goodman and Ranieri (2014), who estimate that the illiquidity discount through the so-called market adjusted pricing (see Section 2) has cost Freddie Mac as much as $1 billion annually.

Arising from the loss of liquidity network externality associated with market frag-

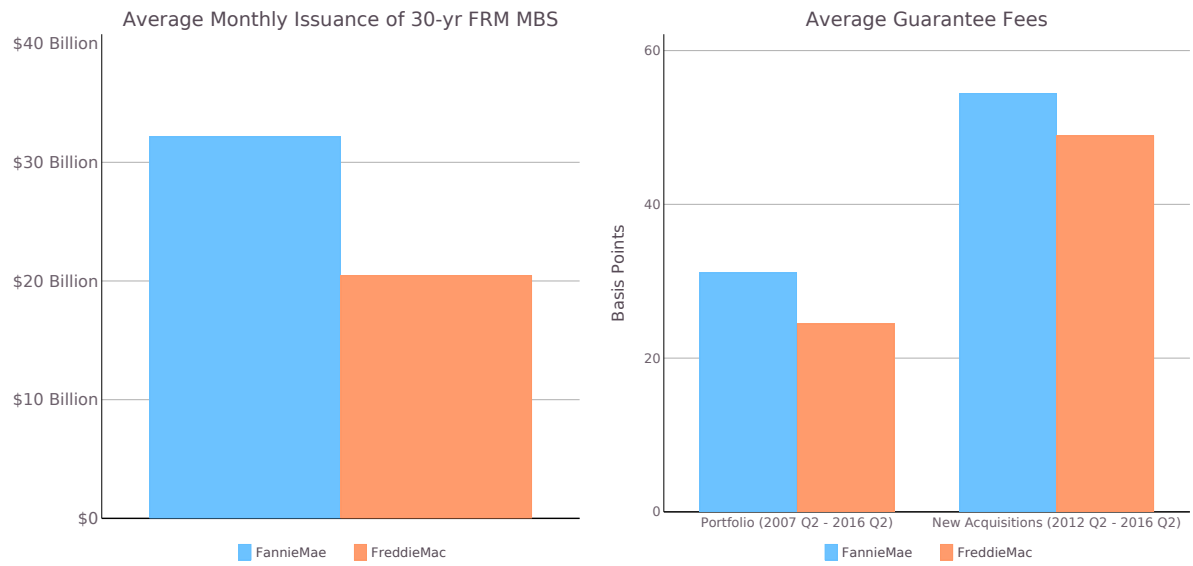

Figure 3: **Fannie Mae and Freddie Mac MBS Issuance Amounts and Guarantee Fees**

The left panel reports the average monthly issuance amount of 30-year TBA-eligible Fannie Mae and Freddie Mac MBS, respectively, from January 1998 to June 2016. The right panel reports the quarterly average of annualized net guarantee fees charged by Fannie Mae and Freddie Mac for new acquisitions from 2012 Q2 to 2016 Q2 and for entire portfolios from 2007 Q2 to 2016 Q2.

mentation, such a cost is ultimately borne by taxpayers given the government-backing of GSEs. One of the main objectives of the FHFA in initiating the market consolidation reform is to reinstate the benefit of liquidity network externality. We now turn to study the effects of market consolidation.

4 Effects of Market Consolidation

In this section, we document the effects of market consolidation by the Single Security Initiative.

4.1 Convergence between Fannie Mae and Freddie Mac MBS

As formulated in Hypothesis 3, although the final UMBS implementation would result in full convergence of Fannie Mae and Freddie Mac MBS in TBA trading by design, the con-

vergence can begin in advance of the final implementation. Hence, we examine changes of TBA liquidity and price in the transition period from July 2016 (when the FHFA sets a firm timetable for the Single Security Initiative) to February 2019 (right before UMBS TBA trading started).

In particular, we run 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 3, the Fannie–Freddie 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 run 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 of the Fannie–Freddie gap in TBA trading cost is quantitatively tiny and statistically insignificant. This is not surprising as the gap in TBA trading cost is quite low in the first place (only about one basis point as reported in Table 2). Instead, from the fourth and fifth columns, we observe that the Fannie-Freddie gap in price and OAS shrank significantly, by about 20-30 cents per $100 par value and 4.5-6.5 basis point respectively. Interestingly, the coefficients become larger over time, indicating greater convergence as the UMBS implementation date approaches.

Turning to the primary market, the last column of Table 3 reports the result of the regression for the Fannie–Freddie gap in issuance amount. Different from the TBA market activities that are fully consolidated after the UMBS implementation, primary market activities of Fannie Mae and Freddie Mac are still separate, so we include the post-implementation period from March 2019 to February 2020 in the analysis. We observe that the gap in issuance amount does not change significantly in the transition period but reduced significantly by about 15% after the final implementation. Furthermore, Figure 4 plots quarterly series of the G-fees of Fannie Mae and Freddie Mac on new mortgage purchases. Similar to issuance amount, we do not observe a convergence in G-fee prior to the

Table 3: **Convergence of Fannie Mae and Freddie Mac MBS**

	Log (Volume)	Log (Volume/Balance)	RTC	Price	OAS	Log (Issuance)
2016/07 to 2017/06	-0.24***	-0.20***	-0.002	-0.21***	4.49***	-0.04
	(0.04)	(0.04)	(0.006)	(0.04)	(0.93)	(0.05)
2017/07 to 2018/06	-0.08	-0.02	0.000	-0.23***	4.83***	-0.02
	(0.08)	(0.08)	(0.007)	(0.05)	(1.08)	(0.06)
2018/07 to 2019/02	-0.20***	-0.12***	-0.001	-0.32***	6.53***	-0.03
	(0.03)	(0.03)	(0.006)	(0.04)	(1.02)	(0.03)
2019/03 to 2020/02						-0.15***
						(0.05)
Observations	44	44	3158	348	348	56
Cohort FE			X	X	X	
Cohort x CPR Diff			X	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$\times$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$\times$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.

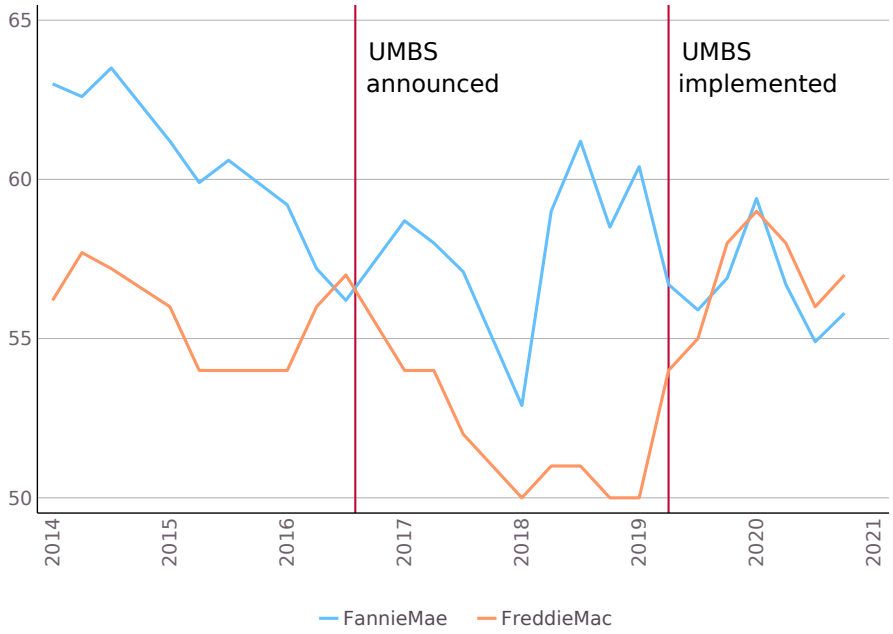

Figure 4: **Guarantee Fees of Fannie Mae and Freddie Mac**

This figure plots quarterly time series of the average annualized guarantee fees (in basis points) on newly securitized mortgages for Fannie Mae and Freddie Mac, respectively. The sample period is 2014 Q2 to 2020 Q1.

UMBS implementation, but the gap dropped sharply afterwards. Regressing Gfee_t^{Fannie} – $\text{Gfee}_t^{Freddie}$ on a post-UMBS dummy delivers a coefficient of -5.2 basis point with high statistical significance.

In sum, we find that (1) TBA trading volume and liquidity premium of Fannie Mae and Freddie Mac MBS greatly converged in anticipation of future market consolidation, (2) there are no significant changes in the difference between Fannie Mae and Freddie Mac TBA trading costs, and (3) issuance amount and G-fee converged significantly, but only after the final UMBS implementation.

4.2 Harmonizing Fannie Mae and Freddie Mac MBS

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

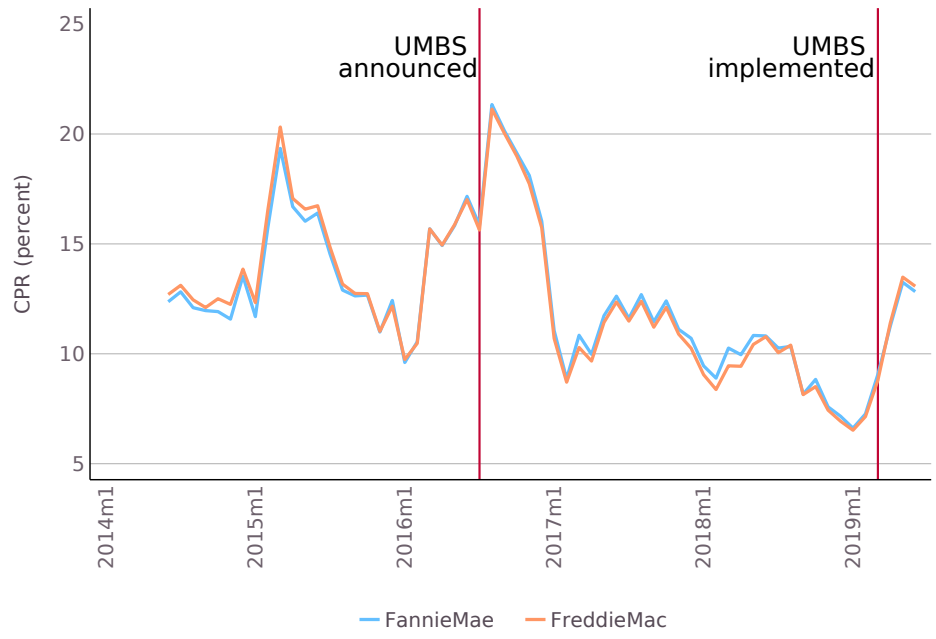

Figure 5: **Fannie–Freddie Gap in Prepayment Speed**

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.

Realized prepayment speeds. First, Figure 5 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. We observe that 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 the UMBS implementation.

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.

Table 4: **Settlements of the Federal Reserve's TBA Purchases**

	TBA Delivery/Outstanding Balance	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.

Data on what specific MBS are delivered to settle TBA contracts are not available in general, to the best of our knowledge. Our analysis takes advantage of the availability of security-level holdings of the Federal Reserve's agency MBS, which are purchased exclusively through TBA contracts. By merging the Federal Reserve's holdings data with MBS characteristics data from eMBS, we recover the settlement records of the Federal Reserve's TBA contracts (see Appendix B for details).[21]

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 sold forward through TBA contracts (Fuster, Lucca, and Vickery, 2021). As reported in Table 4, the regression coefficients are quantitatively small and statistically insignificant, indicating that Fannie Mae and Freddie Mac MBS are indeed equally likely to be delivered to settle TBA contracts after the UMBS implementation.

SP 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

[21] 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. We match the direct settlement data almost exactly.

Table 5: **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 5, 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.

4.3 Comparison to Ginnie Mae

Given the suppressed asset heterogeneity as documented above, liquidity should improve for both Fannie Mae and Freddie Mac MBS 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, which are not part of the Single Security Initiative.

Column (1) in Panel A of Table 6 reports the result of regressing the Fannie–Ginnie difference in TBA trading volume on the three time dummies for the transition period (see Table 3), while column (2) reports the result for Freddie–Ginnie difference. Because the UMBS implementation results in full merging of 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. Results of similar regressions for turnover reported in columns (4)-(6) deliver similar findings.

Turning to trading cost, price, and OAS, Panel B of Table 6 reports the results of regressions of the Fannie–Ginnie and Freddie–Ginnie 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 of UMBS TBAs are used for both Fannie Mae and Freddie Mac). Relative to Ginnie Mae, price 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 quite small and insignificant. In addition, The 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 6 reports the result of regressions of the Fannie–Ginnie and Freddie–Ginnie differences in monthly issuance amount. We observe significant increases in the issuance amount 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–Freddie gap in issuance amount in the transition period and its significance drop after the UMBS implementation, as reported in the last column of Table 3

Ginnie Mae MBS are not an ideal control group because of their different extents of government backing and loan types (see detailed discussions in the Introduction). One of the most important confounding events in the sample period we focus on 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 is likely the reason why we observe a slight increase in OAS and decline in prices during the 2016-17 period for Fannie Mae MBS. However, this confounding effect makes our estimates to be conservative. Overall, results in this section do go against the concern that the Single Security Initiative had negative effects on market quality for Fannie Mae MBS. Instead, significant liquidity improvement of Freddie Mac MBS are accompanied by some

Table 6: **Comparison with Ginnie Mae MBS**

	(1) Fannie-Ginnie	(2) Freddie-Ginnie	(3) GSE-Ginnie	(4) Fannie-Ginnie	(5) Freddie-Ginnie	(6) GSE-Ginnie	(7) Fannie-Ginnie	(8) Freddie-Ginnie
	A: Trading Volume and Issuance							
	Log(Volume)			Log(Volume/Balance)			Log(Issuance)	
2016/07 to 2017/06	-0.02	0.21***	-0.00	0.01	0.22***	0.02	0.06**	0.10**
	(0.04)	(0.06)	(0.04)	(0.05)	(0.06)	(0.05)	(0.03)	(0.04)
2017/07 to 2018/06	0.06	0.14**	0.07	0.11**	0.13*	0.10*	0.20***	0.22***
	(0.06)	(0.07)	(0.05)	(0.06)	(0.07)	(0.05)	(0.04)	(0.05)
2018/07 to 2019/02	0.21***	0.41***	0.23***	0.25***	0.37***	0.24***	0.33***	0.36***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.06)	(0.05)	(0.03)	(0.03)
2019/03 to 2020/02			0.14**			0.12*	0.24***	0.39***
			(0.07)			(0.07)	(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	-0.30**	-0.09		6.32**	1.88		0.005	0.009
	(0.15)	(0.14)		(2.92)	(2.70)		(0.015)	(0.013)
2017/07 to 2018/06	0.14	0.38**		-1.42	-6.09*		0.008	0.011
	(0.19)	(0.19)		(3.34)	(3.31)		(0.014)	(0.014)
2018/07 to 2019/02	0.02	0.36***		-1.65	-8.23***		-0.002	-0.001
	(0.14)	(0.12)		(2.37)	(1.83)		(0.010)	(0.010)
2019/03 to 2020/02	0.14	0.47***		1.20	-7.61***		-0.004	-0.004
	(0.09)	(0.08)		(1.79)	(1.53)		(0.011)	(0.011)
Observations	364	364		364	364		3082	3047
Cohort FEs	X	X		X	X		X	X
Cohort x CPR Diff	X	X		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–Ginnie and Freddie–Ginnie 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 of 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.

improvement of Fannie Mae MBS liquidity, consistent with benefit of liquidity network externality.

5 Conclusion

In this paper, 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 activity of agency MBS were concentrated in the Fannie Mae segment relative to Freddie Mac segment. We further show that the market consolidation reform engineered by the Single Security Initiative improved liquidity of Freddie Mac MBS together with improvement in liquidity of Fannie Mae MBS. We also provide evidence that steps taken by the regulators to align fundamentals of the MBS issued by these two agencies suppressed asset heterogeneity and its potential adverse effects, which is instrumental for the improvement in market liquidity.

Our results expand the existing equity-focused analyses of market fragmentation and liquidity to fixed-income markets. More importantly, 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.

Appendix

A Historical Development of the Agency MBS Market

Fannie Mae was established by the U.S. Congress in 1938, to address the severe mortgage debt defaults and foreclosures as the aftermath of the Great Depression. For thirty years following its inception, Fannie Mae had been a monopoly in the market of mortgage loans, which were mainly FHA-insured mortgages then. Part of it was then 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 mortgage market. Since beginning, Fannie Mae always had a larger market share of mortgage loans than its competitor.

Because of its historical advantage, although not the first to issue an MBS,[22] Fannie Mae has been the dominant player in the agency MBS market since late 1990s. As shown in Frame and White (2005) (Table 1, page 162), Fannie Mae had about $510 billion of outstanding MBS while Freddie Mac had about $460 billion as of 1995; these amounts became $1.3 trillion and $770 billion as of 2003. Moreover, prepayment rates of Freddie Mac MBS were historically faster than those of Fannie Mae MBSs when mortgages were in the money (Goodman and Ranieri, 2014), so are more received by MBS investors. However, Freddie Mac and Fannie Mae MBS prepayment rates have substantially converged in recent years.

B 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.

[22] Ginnie Mae guaranteed the first mortgage pass-through security of an approved lender in 1968. Freddie Mac issued its first mortgage pass-through security in 1971, while Fannie Mae began issuing MBS in 1981 (see Frame and White (2005), McConnell and Buser (2011) and Frame, Fuster, Tracy, and Vickery (2015)).

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 reflects 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).

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 4, 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.

C Additional Results and Robustness Checks

We provide several additional results and robustness checks in this appendix.

First, Table A1 provides estimates of the average Fannie Mae—Freddie Mac gap in price and OAS, similar to those in Table 2 but for three subperiods: before, during, and after the 2008 financial crisis. We observe that the price and OAS differential is larger during and after the 2008 financial crisis than in the period prior to the crisis. This may reflect

a reduction in the ability of dealers to provide liquidity due to balance sheet constraints and heightened post-crisis regulation (Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018); Bao, O'Hara, and Zhou (2018); Duffie (2018)).

Second, Figure A2 present estimates of the average Fannie Mae–Freddie Mac gap in price and OAS for each moneyness cohort and each of the three subperiods. We observe that the price gap and OAS gap of coupon stacks close to par are similar to those for the full sample.

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 top 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 bottom panel normalizes by the cumulative issuance amount within the last 12 months. The sample period is from June 2019 to December 2020.

Table A1: **Differences in Price and OAS for Subsamples**

	Price Gap	OAS Gap	Obs
	(% of par)	(bp)	
Pre-Crisis	0.14***	-2.32***	458
[Jan 1998 to July 2007]	(0.013)	(0.20)	
Crisis	0.42***	-6.59***	365
[Aug 2007 to Dec 2011]	(0.064)	(0.93)	
Post-Crisis	0.30***	-4.74***	409
[January 2012 to June 2016]	(0.059)	(0.71)	
Sample Mean (Full Sample)	0.24	-5.13	
Cohort FE	X	X	
Cohort x CPR Diff	X	X	

This table reports the monthly series mean of price (per $100 of principal) and 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 for the pre-crisis, crisis, and post-crisis samples, respectively. The estimates are obtained by regressions at the cohort*times*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 overall sample period is January 1998 to February 2019, and only moneyness cohorts of CC-2 to CC+6 are included. Standard errors clustered by month are in parentheses. Significant at *p<0.10, **p<0.05, ***p<0.01.

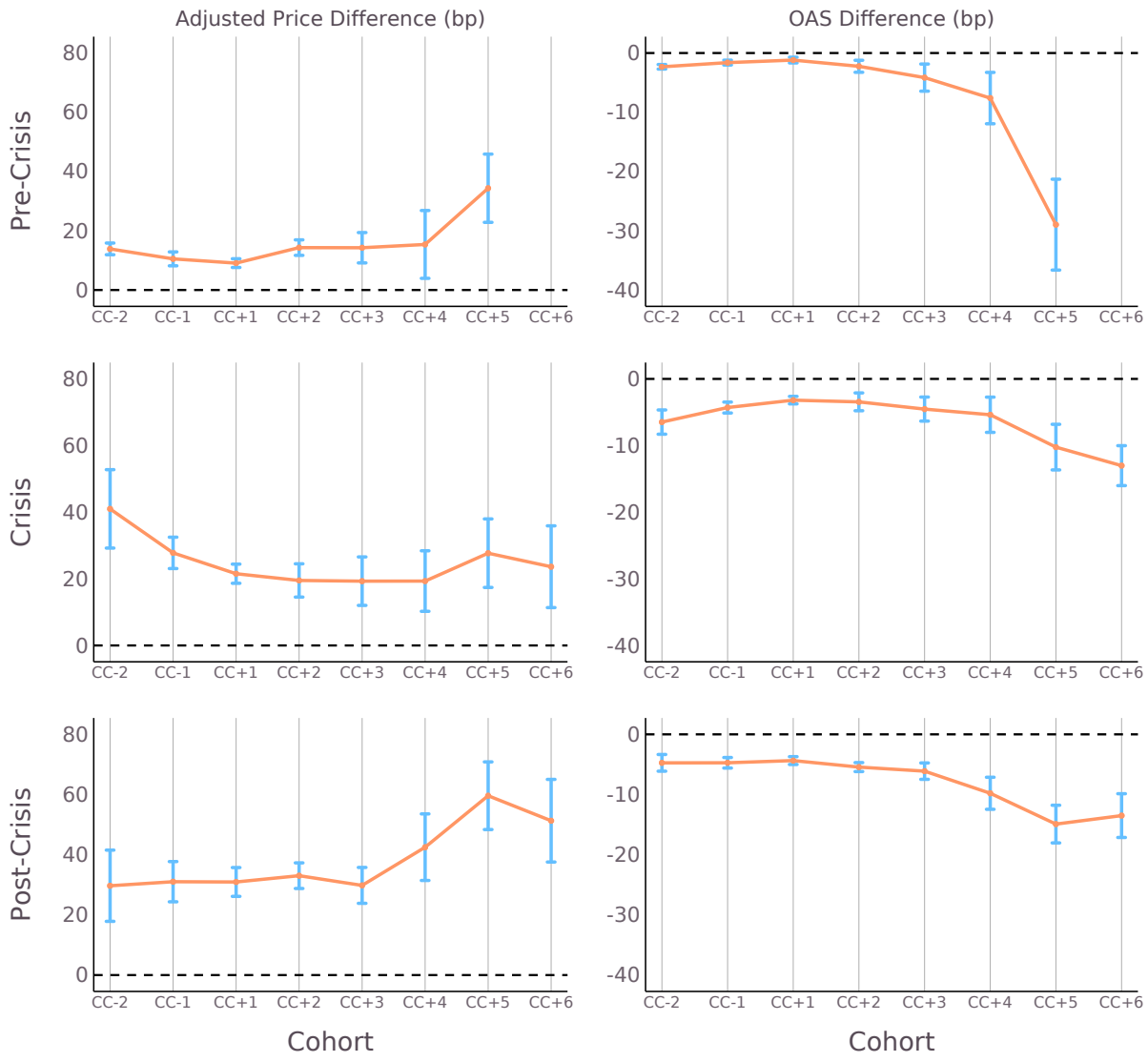

Figure A2: **Cohort Price and OAS Gap Across Different Samples**

This figure reports the monthly series mean of price in cents per $100 of principal (left panel) and OAS in basis points (right panel) of front-month TBA contracts of 30-year agency (average across Fannie Mae and Freddie Mac) MBS for each moneyness cohort and the pre-crisis, crisis, and post-crisis samples, respectively. The estimates are obtained by monthly time series regressions for each moneyness cohort, controlling for the difference in prepayment rate forecast (CPR) of Fannie Mae and Freddie Mac MBS. The overall sample period is January 1998 to February 2019, and only moneyness cohorts of CC-2 to CC+6 are included. The 95% confidence intervals are calculated based on standard errors clustered by month. Significant at *p<0.10, **p<0.05, ***p<0.01.

References

ACHARYA, V. V., M. RICHARDSON, S. V. NIEUWERBURGH, AND L. J. WRIGHT (2011): *Guaranteed to Fail: Fannie Mae, Freddie Mac, and the Debacle of Mortgage Finance*. Princeton University Press.

ALLEN, J., AND M. WITTWER (2021): "Centralizing over-the-counter markets?," Working Paper.

AMIHUD, Y., B. LAUTERBACH, AND H. MENDELSON (2003): "The Value of Trading Consolidation: Evidence from the Exercise of Warrants," *Journal of Financial and Quantitative Analysis*, 38(4), 829–846.

AMIHUD, Y., AND H. MENDELSON (1986): "Asset pricing and the bid-ask spread," *Journal of Financial Economics*, 17(2), 223 – 249.

AN, Y., L. LI, AND Z. SONG (2021a): "Shadow Bank and Fintech Mortgage Securitization," *Johns Hopkins Carey Business School Research Paper No. 21-06*.

AN, Y., W. LI, AND Z. SONG (2021b): "Cohort Trading and Security Design: Theory and Evidence from Agency MBS Markets," Working Paper.

BABUS, A., AND C. PARLATORE (2019): "Strategic Fragmented Markets," *Working Paper*.

BAO, J., M. O'HARA, AND X. A. ZHOU (2018): "The Volcker Rule and corporate bond market making in times of stress," *Journal of Financial Economics*, 130(1), 95 – 113.

BARCLAY, M. J., AND T. HENDERSHOTT (2004): "Liquidity Externalities and Adverse Selection: Evidence from Trading after Hours," *Journal of Finance*, 59(2), 681–710.

BARCLAY, M. J., T. HENDERSHOTT, AND C. M. JONES (2008): "Order Consolidation, Price Efficiency, and Extreme Liquidity Shocks," *Journal of Financial and Quantitative Analysis*, 43(1), 93–121.

BATTALIO, R. H. (1997): "Third Market Broker-Dealers: Cost Competitors or Cream Skimmers?," *Journal of Finance*, 52(1), 341–352.

BENNETT, P., AND L. WEI (2006): "Market structure, fragmentation, and market quality," *Journal of Financial Markets*, 9(1), 49 – 78.

BESSEMBINDER, H., S. JACOBSEN, W. MAXWELL, AND K. VENKATARAMAN (2018): "Capital Commitment and Illiquidity in Corporate Bonds," *The Journal of Finance*, 73(4), 1615–1661.

BESSEMBINDER, H., W. MAXWELL, AND K. VENKATARAMAN (2013): "Trading activity and transaction costs in structured credit products," *Financial Analysts Journal*, 69(6), 55–68.

BESSEMBINDER, H., C. SPATT, AND K. VENKATARAMAN (2019): "A Survey of the Microstructure of Fixed-Income Markets," *Journal of Financial and Quantitative Analysis*.

BOEHMER, B., AND E. BOEHMER (2003): "Trading your neighbor's ETFs: Competition or fragmentation?," *Journal of Banking Finance*, 27(9), 1667 – 1703.

BOYARCHENKO, N., A. FUSTER, AND D. O. LUCCA (2019): "Understanding mortgage spreads," *The Review of Financial Studies*, 32(10), 3799–3850.

CHAO, Y., C. YAO, AND M. YE (2018): "Why Discrete Price Fragments U.S. Stock Exchanges and Disperses Their Fee Structures," *The Review of Financial Studies*, 32(3), 1068–1101.

CHEN, D., AND D. DUFFIE (2021): "Market Fragmentation," *American Economic Review*, forthcoming.

CHERNOV, M., B. DUNN, AND F. LONGSTAFF (2018): "Macroeconomic-driven Prepayment Risk and the Valuation of Mortgage-Backed Securities," *Review of Financial Studies*, 31(3), 1132–1183.

CHOWDHRY, B., AND V. NANDA (1991): "Multimarket Trading and Market Liquidity," *The Review of Financial Studies*, 4(3), 483–511.

DIEP, P., A. L. EISFELDT, AND S. RICHARDSON (2021): "The Cross Section of MBS Returns," *The Journal of Finance*, forthcoming.

DOWNING, C., D. JAFFEE, AND N. WALLACE (2009): "Is the Market for Mortgage Backed Securities a Market for Lemons?," *Review of Financial Studies*, 22–7, 2457–2494.

DUFFIE, D. (2018): "Financial Regulatory Reform After the Crisis: An Assessment," *Management Science*, 64(10), 4835–4857.

ECONOMIDES, N. (1996): "The economics of networks," *International Journal of Industrial Organization*, 14(6), 673 – 699.

FHFA (2012): "A Strategic Plan for Enterprise Conservatorships: The Next Chapter in a Story that Needs an Ending," Washington, D.C.: Federal Housing Finance Agency.

——— (2014): "Request for Input: Proposed Single Security Structure," Washington, D.C.: Federal Housing Finance Agency.

——— (2015): "Fannie Mae and Freddie Mac Single-Family Guarantee Fees in 2015," Washington, D.C.: Federal Housing Finance Agency.

FOUCAULT, T., AND A. J. MENKVELD (2008): "Competition for Order Flow and Smart Order Routing Systems," *Journal of Finance*, 63(1), 119–158.

FRAME, W. S., A. FUSTER, J. TRACY, AND J. VICKERY (2015): "The Rescue of Fannie Mae and Freddie Mac," *Journal of Economic Perspectives*, 29(2), 25–52.

FRAME, W. S., AND L. J. WHITE (2005): "Fussing and Fuming over Fannie and Freddie: How Much Smoke, How Much Fire?," *Journal of Economic Perspectives*, 19(2), 159–184.

FRIEWALD, N., R. JANKOWITSCH, AND M. SUBRAHMANYAM (2017): "Transparency and liquidity in the structured product market," *Review of Asset Pricing Studies*, 7(2), 316–348.

FUSARI, N., W. LI, H. LIU, AND Z. SONG (2021): "Asset Pricing with Cohort-Based Trading in MBS Markets," *Journal of Finance*, forthcoming.

FUSTER, A., D. LUCCA, AND J. VICKERY (2021): "Mortgage-Backed Securities," Discussion paper.

GABAIX, X., A. KRISHNAMURTHY, AND O. VIGNERON (2007): "Limits of Arbitrage: Theory and Evidence from the Mortgage-Backed Securities Market," *Journal of Finance*, 2, 557–595.

GAO, P., P. SCHULTZ, AND Z. SONG (2017): "Liquidity in a Market for Unique Assets: Specified Pool and TBA Trading in the Mortgage Backed Securities Market," *Journal of Finance*, 72-3, 1119–1170.

——— (2018): "Trading Methods and Trading Costs for Agency Mortgage Backed Securities," *Journal of Investment Management*, 16, 29–46.

GETE, P., AND M. REHER (2020): "Mortgage Securitization and Shadow Bank Lending," *The Review of Financial Studies*, hhaa088.

GOODMAN, L., AND L. RANIERI (2014): "Charting the Course to a Single Security," *Urban Institute Housing Finance Policy Center Commentary*.

HE, Z., AND Z. SONG (2020): "Agency MBS as Safe Assets," *working paper*, Johns Hopkins Carey Business School.

HENDERSHOTT, T., AND C. M. JONES (2005): "Island Goes Dark: Transparency, Fragmentation, and Regulation," *The Review of Financial Studies*, 18(3), 743–793.

HENDERSHOTT, T., AND H. MENDELSON (2000): "Crossing Networks and Dealer Markets: Competition and Performance," *Journal of Finance*, 55(5), 2071–2115.

HUANG, M. (2003): "Liquidity shocks and equilibrium liquidity premia," *Journal of Economic Theory*, 109(1), 104 – 129.

HUH, Y., AND Y. S. KIM (2020): "The Real Effects of Secondary Market Trading Structure: Evidence from the Mortgage Market," *Working Paper*, Board of Governors of the Federal Reserve System.

——— (2021): "Cheapest-to-Deliver Pricing and Endogenous MBS Heterogeneity," Board of Governors of the Federal Reserve System, Working Paper.

KRISHNAMURTHY, A., AND A. VISSING-JORGENSEN (2013): "The Ins and Outs of LSAPs," Working Paper.

LEVIN, A., AND A. DAVIDSON (2005): "Prepayment Risk-and Option-Adjusted Valuation of MBS," *Journal of Portfolio Management*, 31(4), 73–85.

LI, W., AND Z. SONG (2020): "Asset Heterogeneity, Market Fragmentation, and Quasi-Consolidated Trading," *Working Paper*.

MCCONNELL, J. J., AND S. A. BUSER (2011): "The Origins and Evolution of the Market for Mortgage-Backed Securities," *Annual Review of Financial Economics*, 3(1), 173–192.

MENDELSON, H. (1982): "Market Behavior in a Clearing House," *Econometrica*, 50(6), 1505–1524.

——— (1985): "Random competitive exchange: Price distributions and gains from trade," *Journal of Economic Theory*, 37(2), 254 – 280.

——— (1987): "Consolidation, Fragmentation, and Market Performance," *Journal of Financial and Quantitative Analysis*, 22(2).

O'HARA, M., AND M. YE (2011): "Is market fragmentation harming market quality?," *Journal of Financial Economics*, 100(3), 459 – 474.

PAGANO, M. (1989): "Trading Volume and Asset Liquidity*," *The Quarterly Journal of Economics*, 104(2), 255–274.

ROBERTS, D., A. SARKAR, AND O. SHACHAR (2018): "Bank Liquidity Creation, Systemic Risk, and Basel Liquidity Regulations," (852).

SCHULTZ, P., AND Z. SONG (2019): "Transparency and Dealer Networks: Evidence from the Initiation of Post-Trade Reporting in the Mortgage Backed Security Market," *Journal of Financial Economics*, 133, 113–133.

SONG, Z., AND H. ZHU (2019): "Mortgage Dollar Roll," *The Review of Financial Studies*, 32(8), 2955–2996.

VAYANOS, D. (1998): "Transaction Costs and Asset Prices: A Dynamic Equilibrium model," *The Review of Financial Studies*, 11(1), 1–58.

VAYANOS, D., AND T. WANG (2007): "Search and endogenous concentration of liquidity in asset markets," *Journal of Economic Theory*, 136(1), 66 – 104.

VAYANOS, D., AND P.-O. WEILL (2008): "A search-based theory of the on-the-run phenomenon," *Journal of Finance*, 63, 1361–1398.

VICKERY, J., AND J. WRIGHT (2011): "TBA Trading and Liquidity in the Agency MBS Market," *Federal Reserve Bank of New York Economic Policy Review*, 19.

WEILL, P.-O. (2008): "Liquidity premia in dynamic bargaining markets," *Journal of Economic Theory*, 140(1), 66–96.