An agency problem in the MBS market and the solicited refinancing channel of large-scale asset purchases

John Kandrac* Bernd Schlusche‡

Federal Reserve Board *Federal Reserve Board*

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ABSTRACT

In this paper, we document that mortgage-backed securities (MBS) held by the Federal Reserve exhibit faster principal prepayment rates than MBS held by the rest of the market. Next, we show that this stylized fact persists even when controlling for factors that affect prepayment behavior, and thus determine the MBS that are delivered to the Federal Reserve. After ruling out several potential explanations for this result, we provide evidence that points to an agency problem in the secondary market for MBS, which has not previously been documented, as the most likely explanation for the abnormal prepayment behavior of Federal Reserve-held MBS. This agency problem—a key feature of the MBS market—arises when originators of mortgages that underlie the MBS no longer share in the prepayment risk of the securities, thereby increasing incentives to solicit refinancing activity. Therefore, Federal Reserve MBS holdings acquired from originators as a result of large-scale asset purchases can help stimulate economic activity through a so-called "solicited refinancing channel." Finally, we provide an estimate of the additional refinancing activity resulting from the solicited refinancing channel in the years after the Federal Reserve's first MBS purchase program, demonstrating that this channel conveyed savings on monthly mortgage payments to homeowners.

JEL classification: E52, G01, G21, R38

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*Board of Governors of the Federal Reserve System. E-mail: john.p.kandrac@frb.gov. Tel.: +1 202 912 7866.

‡Board of Governors of the Federal Reserve System. E-mail: bernd.schlusche@frb.gov. Tel.: +1 202 452 2591.

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1. Introduction

The Federal Reserve's response to the financial crisis that reached a climax in 2008 entailed a number of unconventional policy measures. Initially, a number of credit and liquidity facilities were implemented in order to ease pressure in financial markets, which put considerable downward pressure on interest rates. As short-term interest rates approached their zero lower bound and the economy remained weak, the Federal Reserve initiated the first of several large-scale asset purchase (LSAP) programs (also known as quantitative easing or QE) in an attempt to spur a more rapid recovery in financial conditions and the economy.

Among all of the unconventional policy measures, LSAP programs that involved purchases of a various mix of Treasury securities, agency debt, and agency mortgage-backed securities (MBS) have garnered the most attention among financial market participants and academics.[1] Indeed, the adoption of QE by central banks in response to the recent financial crisis provided the opportunity for researchers to empirically evaluate the effects of these programs and assess the degree to which such programs can be relied upon by central banks restricted by the zero lower bound. A primary goal of LSAPs is to increase the prices of the aforementioned securities and their close substitutes, thereby lowering longer-term interest rates important to economic activity (Bernanke (2010)).[2] Consequently, studies evaluating the effects of QE have focused almost exclusively on the effects of central bank securities purchases and holdings on asset prices and yields (e.g., Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Hancock and Passmore (2011), Neely (2012), D'Amico and King (2013), and Gilchrist and Zakrajšek (2013)).

In this paper, we analyze the prepayment behavior of MBS held in the Federal Reserve's System Open Market Account (SOMA) portfolio after the first QE program. We document that MBS held by the Federal Reserve exhibit higher principal prepayment rates than similar

[1] Throughout the paper, we use the term "MBS" to refer to securities backed by residential mortgages but not those backed by commercial mortgages.

[2] The theoretical basis for this mechanism is captured in preferred habitat and portfolio balance theories, both of which rest on the presumption that the relative price of an asset is, to a considerable extent, dependent on the amount of the asset that is available to investors as a result of imperfect substitutability. These theories go back to Modigliani and Sutch (1966) and Tobin (1969), but have recently garnered popularity as studies have added rigorous micro foundations to these theories (see, for example, Andres et al. (2004) and Vayanos and Vila (2009)).

MBS held by the market and provide some explanations for this result. Specifically, we show that the difference in prepayment rates is, to a large extent, explained by the Federal Reserve's practice of conducting its MBS purchases in the to-be-announced (TBA) market. MBS trade in the TBA market on a "cheapest-to-deliver" basis and, consequently, the Federal Reserve was delivered MBS that carry relatively high prepayment risk.[3] According to our results, however, a substantial portion of the difference in prepayment rates of Federal Reserve-held and market-held MBS cannot be attributed to factors that primary dealers use to determine which MBS to deliver into TBA contracts.[4]

We then investigate several potential explanations that may account for the "unexplained" difference in prepayment rates. Based on our test results, the most likely explanation for the faster prepayment speeds of Federal Reserve-held MBS is that an agency problem arises once the originators of mortgages that underlie the MBS no longer share in the prepayment risk of the securities once they are sold to the Federal Reserve. An analogous agency problem is often cited to explain the otherwise puzzling prepayment behavior exhibited by mortgages that are originated by third parties such as mortgage brokers (LaCour-Little and Chun (1999)). In fact, the incentives for third party originators to "churn" mortgage borrowers in order to earn refinancing fees are strong enough that lenders include non-solicitation clauses in their agreements with mortgage brokers or loan correspondents that sell their mortgage products. However, since non-solicitation agreements are interpreted very narrowly, and since monitoring and enforceability may be prohibitively costly, mortgages originated by third parties exhibit notably higher rates of prepayment. Similarly, when an investor (such as the Federal Reserve) purchases MBS, some of the securities will be purchased from institutions that originated the mortgages.[5] Importantly,

[3] In fact, the removal of prepayment risk from private portfolios—one of the underlying presumptions of the asset-price effects identified in the aforementioned studies—was a goal of the Federal Reserve's MBS purchases. As for MBS, the price effect from the Federal Reserve's purchases comprises a duration effect—that is, a decrease in investors' required compensation for bearing interest rate risk—and a convexity effect, which describes the decrease in compensation for bearing the prepayment risk associated with holding MBS.

[4] Although Krishnamurthy and Vissing-Jorgensen (2013) and Himmelberg et al. (2013) note that mortgage pools held by the Federal Reserve prepay faster than pools not held by the Federal Reserve, these studies appeal to the "cheapest-to-deliver" nature of the TBA market in which the Federal Reserve purchased MBS and do not empirically investigate whether the difference in prepayment speeds can be *fully* explained by the characteristics of the securities.

[5] After the financial crisis, most mortgages were originated by the four largest banks, which also service the

the originating institution no longer shares in the prepayment risk of the MBS or, to the extent that only a portion of the MBS is purchased, bears less of the prepayment risk than prior to the QE program. Consequently, mortgage lenders have a higher incentive to solicit refinancings for previously extended loans that have been transferred off of their balance sheets along with much of the prepayment risk.

Focusing on Federal Reserve MBS holdings acquired as a result of QE1, we use regression and propensity score matching techniques to demonstrate economically significant abnormal prepayment activity of between two and six percentage points in the two years after the end of QE1. Testing this agency problem requires analyzing MBS that are held by investors that cannot solicit refinancings, so the Federal Reserve's portfolio provides an ideal cross-section of MBS for this exercise. In addition, we present mortgage-level analysis that supports the existence of such an agency problem by showing that mortgages that are more likely to be sold by originators prepay more quickly than nearly identical mortgages that remain in originators' whole loan portfolios.

An agency problem that generates higher prepayment rates for Federal Reserve MBS holdings highlights a new transmission mechanism by which QE can work, which we refer to as the "solicited refinancing channel." Because MBS prepayments are overwhelmingly driven by refinancing activity rather than ongoing curtailment payments, more rapid prepayment rates imply savings for homeowners on their monthly mortgage payments. These monthly savings could translate into higher levels of consumption and/or more rapid improvements in household balance sheets, which may have been particularly important in the years following the recession. Thus, if the Federal Reserve purchases MBS that would have otherwise remained on the balance sheets of banks and other originators, QE programs can have stimulative effects that work through channels operating alongside those that affect asset prices and generate reductions in longer-term interest rates. Of course, the stimulative effect of this channel depends on the presence of the asset price channels identified in previous work, because the extent of the fall in interest rates will determine

majority of the MBS in our sample. Large institutions securitize whole loan mortgages for various reasons, including beneficial liquidity characteristics, credit guarantees provided by the GSEs, and regulatory benefits conveyed by the lower capital risk weights carried by MBS.

the total savings homeowners can realize through refinancing. We present lower-bound estimates that, as a result of MBS purchases associated with QE1, the solicited refinancing channel can account for at least $16 billion in additional refinancing activity over the following years.

Therefore, the literature documenting the effects of the Federal Reserve's LSAPs on rates in primary and secondary mortgage markets is most relevant for our study.[6] For example, Hancock and Passmore (2011) find that the Federal Reserve's MBS purchases as part of the first LSAP program significantly lowered mortgage rates. Krishnamurthy and Vissing-Jorgensen (2011) study the effects of the first two LSAP programs across several asset classes, and conclude that MBS purchases were indeed effective in lowering MBS yields. In contrast, Stroebel and Taylor (2012) find that after controlling for prepayment and credit risks, only a small portion of the declines in mortgage spreads can be explained by the purchase programs.

Our study is also related to Fuster and Willen (2010) who focus on the effects of QE1 on the primary market for MBS. Using event study methodology, Fuster and Willen (2010) document an increase in refinancing activity upon program announcement and show that this increase is attributable to sharp declines in mortgage rates following the program announcement. Our study differs from Fuster and Willen (2010) because we document that Federal Reserve MBS *ownership* may lead to an increase in refinancing activity for those MBS over and above that caused by a decrease in mortgage rates. That is, even though the potency of our channel depends on the presence of interest rate effects as a result of QE1, its existence is explained by an agency problem in the secondary market for MBS that is induced by Federal Reserve MBS ownership, as opposed to the asset price effects of QE1. Furthermore, this agency problem represents an interesting and important feature of the MBS market and, to the best of our knowledge, has not previously been documented in the literature.

[6] Most other studies of the Federal Reserve's LSAPs focus on their effects on Treasury yields. For example, using a cross-sectional dataset at the security-level, D'Amico and King (2013) document a statistically significant and economically meaningful impact of the Federal Reserve's Treasury purchases on yields of Treasuries and of their close substitutes. Other studies, such as Swanson (2011), Gagnon et al. (2011), and Wright (2012), rely on event studies to provide evidence for significant effects of the Federal Reserve's Treasury purchase programs on Treasury yields. Focusing on the "default risk channel", Gilchrist and Zakrajšek (2013) find that the LSAP announcements led to a substantial reduction in the cost of insurance against corporate defaults.

The remainder of our paper proceeds as follows: Section 2 describes pertinent details of the Federal Reserve's MBS purchases during QE1, with a focus on the to-be-announced secondary market for MBS. Section 3 describes the data. Section 4 presents the empirical methods and discusses the results. Section 5 discusses possible explanations for the abnormal prepayment speeds of Federal Reserve-held MBS. Section 6 describes the "solicited refinancing channel" and demonstrates the contribution of this channel to additional refinancing activity subsequent to QE1. Section 7 concludes.

2. QE1 MBS Purchases and the To-Be-Announced MBS Market

On November 25, 2008, the Federal Reserve announced that it would initiate a program to purchase $100 billion of direct government-sponsored enterprise (GSE) debt and up to $500 billion in GSE-guaranteed MBS (also referred to as agency MBS). This program—which came to be known as QE1 as it represented the first of several large-scale asset purchase programs conducted by the Federal Reserve—was undertaken to reduce the cost and increase the availability of credit available to homeowners, which would in turn support housing markets and foster improved conditions in financial markets more generally.

Due to the specialized technological and operational requirements associated with MBS purchases, the Federal Reserve retained several investment managers to transact in the agency MBS market. Hiring agents to act on behalf of the Open Market Trading Desk (the Desk) at the Federal Reserve Bank of New York (FRBNY) allowed for a quicker and more efficient implementation of MBS purchases, which began on January 5, 2009 and continued thereafter on a daily basis. Although the investment managers worked in close consultation with staff at the Desk, employing outside firms to execute the MBS purchases potentially presented an agency risk.

In order to accommodate the relatively large purchases under the program, the investment managers conducted transactions in the highly liquid to-be-announced (TBA) market. The TBA market allows for the forward trading of agency MBS based upon a handful of parameters under

which mortgage pools can be considered interchangeable. At the time of a trade in the TBA market (which may take place up to three months prior to settlement), only the issuer, maturity, coupon, face value, price, and the settlement date are agreed upon. Thus, buyers in the TBA market agree to purchase MBS at a future date without knowing the CUSIPs that will ultimately be delivered. Two days prior to the contracted settlement date, the seller of the agency MBS will notify the buyer of the identity of the MBS pools that will be delivered to honor the transaction.

As a result of this information asymmetry, the TBA market is a market for lemons and TBA transactions are said to trade on a "cheapest-to-deliver" (CTD) basis as sellers select the lowest value securities among eligible MBS in their inventory.[7] Importantly, the primary source of differences in agency MBS valuations—and therefore the primary determinant of the CTD securities—is prepayment risk. Downing et al. (2009) document this adverse selection issue by identifying CTD securities and demonstrating that these securities indeed possess unfavorable prepayment characteristics when compared with other MBS. Although the GSEs impose standards for the mortgages that underlie securitized mortgage pools eligible for the TBA market, variation in loan sizes, age, geography, and other characteristics are evidently used to identify MBS that are likely to see higher prepayment rates. Despite this adverse selection issue, however, over 90 percent of agency MBS trading takes place in the TBA market (Vickery and Wright (2013)) and, when compared to other U.S. fixed income markets, daily trading volumes are second only to those observed in the market for U.S. Treasuries.

Fortunately, CTD trading in the TBA market allows us to control for the observables that dealers use to identify CTD securities.[8] Of course, the CTD nature of the TBA market implies that securities delivered to the Federal Reserve would be of similar quality on average to MBS delivered to other investors purchasing in TBA securities. Further, the inability of buyers in the TBA market to select delivered securities dramatically limits any possible agency risk presented by the Federal Reserve's use of outside investment managers during QE1.

[7] This feature of the TBA market is analogous to the Treasury futures market, which also trades on a CTD basis. For more information on this and other characteristics of the TBA market, see Vickery and Wright (2013).

[8] In section 5, we address the possibility that dealers could select on potentially unobservable characteristics.

Following their meeting on March 18, 2009, the FOMC released a statement that allowed for an additional $750 billion of agency MBS purchases, bringing total authorized purchases to $1.25 trillion. At the same meeting, the FOMC also decided to expand agency debt purchases and acquire $300 billion of longer-term Treasury securities. As then-Chairman Bernanke would later explain, a primary goal of these purchases was to increase the prices of the purchased securities and their close substitutes, thereby lowering longer-term interest rates important to economic activity (Bernanke (2010)). In September of that year, the FOMC committed to purchase the full $1.25 trillion of agency MBS, and explained that the purchase program would be completed in March of 2010. A few weeks prior to the end of QE1, internal staff at the Desk began executing agency MBS purchases, alternating trading days with the sole remaining outside investment manager. However, purchases continued to be conducted in the TBA market, and therefore nearly all MBS settlement associated with QE1 had taken place by June 2010.[9]

Table 1 contains a summary of the operations conducted as part of QE1. As shown in the table, purchases were concentrated in Fannie Mae and Freddie Mac securities with a 30-year original term to maturity. Note that, per TBA guidelines, coupon rates on TBA transactions vary in 1/2 percentage point increments, reflecting the MBS pools that will be delivered. We now turn to a discussion of our data, which includes a description of the filters and controls that can be used to appropriately compare Federal Reserve holdings with a wider universe of TBA-eligible MBS.

3. Data

In order to evaluate the effect of Federal Reserve MBS ownership on prepayment rates, we require data on Federal Reserve MBS holdings and characteristics for the universe of agency MBS. First, we compile a list of MBS CUSIPs held in the Federal Reserve's SOMA portfolio, which is regularly published by the FRBNY. In order to achieve a more homogenous set of MBS, we keep only 30-

[9] As of June 2010, $9.2 billion of Fannie Mae 5.5 percent coupon securities had yet to settle. As a result, the Open Market Trading Desk conducted coupon swap operations in order to acquire agency MBS that were more readily available for settlement. For the purposes of our analysis below, we ignore these securities.

year MBS that were issued by Fannie Mae and Freddie Mac.[10] As summarized in Table 1, these securities were by far the most commonly purchased during QE1. Beginning our sample in June 2010 (three months after the end of the QE1 MBS purchases), the remaining principal balance of these securities held in the SOMA portfolio was about $980 billion. Note that this figure is slightly below the par value of purchases of these securities, which totaled about $1.08 trillion. This difference can be attributed to principal payments received on the purchased securities over the course of QE1.

Next, we use data provided by eMBS Inc. (a widely referenced MBS analytics provider) to compile characteristics for the universe of 30-year Fannie Mae- and Freddie Mac-issued MBS that were TBA-eligible as of June 2010. Of these securities, we keep only those with fixed-coupons that were purchased by the Federal Reserve during QE1 (shown in the top panel of Table 1). Since Federal Reserve MBS purchases were concentrated in relatively unseasoned MBS, we remove those MBS with production years—also known as "vintages"—that are much older than those held in the SOMA portfolio. Specifically, for each coupon, we identify the production years that compose at least 95 percent of Federal Reserve holdings, and drop all earlier vintages. This results in a sample that contains the following vintages (by coupon): 2009 or later for the 4.0 percent coupon, 2005 or later for the 4.5 percent and 5.0 percent coupons, 2003 or later for the 5.5 percent coupon, and 2006 or later for the 6.0 percent and 6.5 percent coupons. Additionally, we drop those CUSIPs in each coupon that have prefix identifiers other than those purchased by the Federal Reserve.[11] Finally, we remove pools with fewer than 25 loans (though the results below are not sensitive to the precise cutoff). Low-loan pools are dropped since monthly prepayment

[10] Because we conduct much of our analysis at the coupon-level, we also exclude the 3.5 percent coupon securities since only 36 CUSIPs were delivered to satisfy less than $250 million in purchases.

[11] Pool prefixes are used to identify important characteristics of the mortgages that underlie each CUSIP. For example, pools of adjustable-rate mortgages will have a different prefix identifier than a 30-year fixed rate pool, which will in turn have a different prefix identifier than a 15-year fixed rate pool. Importantly, prefix identifiers can be used to indicate which securities will command a premium and trade in the specified pool market rather than the TBA market. For more examples of prefix identifiers, see `http://www.fanniemae.com/resources/file/mbs/pdf/pool-prefix-glossary.pdf`. The list of prefix identifiers purchased by the Federal Reserve for each coupon is available from the authors upon request.

rates can become outliers when even a single refinancing occurs. In total, these filters reduce the universe of CUSIPs in our sample from 323,836 to 84,565.

Figure 1 displays the substantial differences in monthly prepayment rates between securities held in SOMA (the dashed lines) and those held by the market (the solid lines) over the 24 months immediately following QE1. Compared with securities held by private investors, prepayment rates are systematically higher for securities purchased during QE1 and held in the SOMA portfolio. The inset tables in each panel of Figure 1 list the total prepayment rates realized from June 2010 through June 2012. Averaging across the coupon stack displayed in Figure 1, prepayment rates on securities held in the SOMA portfolio were about 7 percentage points faster over this two-year period. Weighting by the number of CUSIPs in each coupon reveals that SOMA-held MBS had prepayment rates that were just over 9 percentage points faster than market-held securities.

In Table 2, we present selected descriptive statistics for our sample. For each coupon, we distinguish between those CUSIPs that are held by the Federal Reserve (labeled "SOMA") and those that are not (labeled "Market"). SOMA securities indeed possess some features consistent with faster prepayment rates. For example, SOMA-held MBS have a larger weighted-average loan size.[12] However, systematic differences in other characteristics between SOMA- and market-held securities are either smaller than one might naively expect, nonexistent, or consistent with *slower* prepayment rates. This relative similarity is likely due to a combination of three factors. First, our exclusion criteria detailed above removed many market-held MBS that would have traded in the specified pool market and would thus not be considered part of the CTD cohort traded in the TBA market. Second, a nontrivial amount of homogeneity is imposed on MBS eligible for TBA trading, as outlined in Vickery and Wright (2013). For example, the securitization process involves a relatively limited number of issuers, is likely to produce geographic diversification, and sets restrictions on interest rates deliverable into a single security. Moreover, loans eligible for agency securitization are subject to constraints on loan size, borrower types, and minimum down payments. A third reason for the relative similarity between the SOMA and market portfolios

[12] Detailed descriptions of the data in Table 2 can be found in the table notes.

is that primary dealers, with whom the Federal Reserve transacts, may have not been able to efficiently select among their inventory given the large volume of Federal Reserve purchases. Similarly, the expectation of rising rates implied by the swap curve during QE1 may have reduced the incentive of investors to deliver faster prepaying securities. This is because principal prepayments made at par are more attractive to investors holding MBS that are trading at a discount.

4. Empirical Methods and Results

4.1. Regression Results

In order to quantify the extent to which abnormal prepayment rates of SOMA-held MBS are explained by CTD characteristics of these securities versus effects related to Federal Reserve ownership, we begin by running cross-sectional regressions of CUSIP-level prepayment rates on a dummy variable indicating Federal Reserve ownership and a set of control variables. Formally, we estimate the following regression separately for each coupon:

$$\text{TPR}_i = \alpha + \beta \textit{Fed ownership}_i + \boldsymbol{\gamma'} \boldsymbol{x_i} + \varepsilon_i, \tag{1}$$

where TPR_i denotes the total prepayment rate of CUSIP i, computed as the amount of prepayments on security i from June 2010 through June 2012 divided by the remaining principal balance as of June 2010. Importantly, TPR_i excludes scheduled principal payments. The explanatory variable of interest, $\textit{Fed ownership}_i$, is a dummy variable that equals one if security i is held by the Federal Reserve and zero otherwise. The vector $\boldsymbol{x_i}$ contains control variables that have previously been shown to affect prepayment speeds (see, for example, Archer et al. (1996) and Green and LaCour-Little (1999)) and are used by dealers to determine which securities to deliver into TBA contracts. Focusing on the total prepayment rate allows us to examine the cross-sectional variation in prepayment speeds as a function of CTD characteristics near the time of the transfer of MBS to the Federal Reserve. Hence, the purpose of our model is different from prepayment models that are designed to explain month-to-month variations in prepayment rates.

The first two control variables are *loan age* and *(loan age)*^{2}, which capture the non-linear effects of aging on a security's prepayment risk. Generally, borrowers are disinclined to refinance a recently originated mortgage or move to a different home immediately after purchasing a property. As a result, prepayment rates are normally very low in the months following mortgage closing before ramping up substantially and leveling off. A very seasoned security, however, may be subject to a "burnout" effect. Burnout describes the phenomenon that loan pools become less responsive to refinancing incentives over time. This is because those borrowers that have failed to take advantage of previous refinancing opportunities—perhaps because of higher refinancing costs—are less likely to refinance in the future. In order to account for differential prepayment incentives across pools, we include the weighted-average *coupon* on the underlying loan pool as a control variable. Furthermore, we include the weighted-average *loan size* of a pool in our set of controls; securities with small loan sizes are likely to prepay more slowly than securities with larger loan sizes because it is more difficult for borrowers with small loans to financially justify the fixed costs of refinancing. Moreover, we include the interaction term *coupon* $\times$ *loan age* as the relationship between the refinancing incentive and prepayment may depend on the age of the loans in a pool. More seasoned pools may respond more slowly to the same refinancing opportunity than less seasoned pools. *Factor*, which is the fraction of the original principal balance that remains to be repaid, is added as a control variable as it is indicative of the cumulative refinancing a security has experienced. Even though somewhat related to *loan age*, *factor* may capture persistence in prepayment speeds. Finally, we include a dummy variable that equals one if a security is Freddie Mac-guaranteed and zero otherwise. This variable allows us to control for differences in prepayment speeds between Freddie Mac and Fannie Mae securities, which may partially explain the observed difference in prices of Fannie Mae and Freddie Mac TBA securities.

In some specifications, the weighted-average credit score (*FICO*), the share of loans originated by a third party (*TPO share*), and the share of loans in the pool that were originated as a result of a previous refinancing (*refi share*) are used as additional controls. Our priors for the first two variables are clear: a borrower with a strong credit history is more likely to refinance

than a borrower with a lower credit score, and loans originated by a third party generally have increased prepayment risk. The effect of *refi share* on prepayment speeds is less clear as the variable does not differentiate between "rate refinancing" and "cash-out refinancing," which tend to have opposite effects on prepayment speeds (see, e.g., Fabozzi (2005)). While rate refinancing may improve a borrower's credit and therefore lead to an increase in prepayments, cash-out refinancing generally increases a borrower's leverage and lowers her credit, leading to slower prepayments.[13] Finally, *vintage* and *geographic dummy* variables are included in some specifications to capture differences in prepayment speeds between different production years as well as regional differences in prepayment behavior. Geographic controls can account for alternate sources of variation in prepayment speeds, such as differences in house price appreciation as well as differences in realized mobility, which may also contribute meaningfully to prepayment rates as discussed in Clapp et al. (2000).

We estimate equation (1) by coupon using ordinary least squares.[14] Table 3 reports the average effects of *Fed ownership* and various control variables on prepayment rates for the two years following QE1. The first set of columns shows the estimation results for 4.0 percent coupon securities. We report these results for completeness but caution against drawing any conclusions from the estimates as these securities are unseasoned securities with very low prepayment rates that makes reliable inference very difficult.[15]

Turning to the baseline results for 4.5 percent coupon securities (reported in column (1)), we observe statistical significance for *fed ownership* and various control variables. The positive coefficient on *loan age* in conjunction with the negative coefficient on *(loan age)*^{2} reflect the expected aging-related prepayment path for MBS; prepayments initially increase as a security ages, then level off, and finally decline when a security becomes well aged. As expected, the higher

[13] During our sample period, rate refinancings are presumably predominant as a high rate of cash-out refinancings tends to occur in periods with solid home price appreciation and loose credit standards, neither of which characterized our sample period.

[14] To more appropriately model a proportional outcome, we also estimate a fractional response model using GLM and obtain nearly identical results. These results are available from the authors upon request.

[15] Unlike other coupons, recall that our exclusion criteria removed all 4.0 percent coupons that were produced prior to QE1. Refinancings in such unseasoned securities can be driven by highly idiosyncratic factors. Consequently, traditional relationships between prepayments and various explanatory variables may not hold.

the weighted-average *coupon* and the larger the weighted-average *loan size* of the underlying loan pool, the higher the prepayment rate. The negative coefficient on *factor* suggests that the more has repaid in a pool the higher is the subsequent prepayment rate. This result could be due to persistence in prepayment speeds. Consistent with our prior, we obtain a negative coefficient estimate for the interaction variable *coupon* $\times$ *loan age*; that is, the more seasoned a security, the weaker prepayments for a particular level of refinancing incentive as the savings from a refinancing are lower for aged loans all else equal, and may not justify incurring refinancing fees. Moreover, we find that Freddie Mac securities exhibit faster prepayments than otherwise identical Fannie Mae securities.

Importantly, even after accounting for CTD effects by conditioning on various factors that explain prepayment behavior of MBS, securities held by the Federal Reserve prepay more quickly than those securities not held in SOMA, as indicated by the significantly positive coefficient estimate on *Fed ownership*. As shown in column (2), these results are mostly insensitive to the inclusion of *vintage* and *geographic dummy* variables, though these dummies are frequently included in prepayment models and their inclusion increases the explanatory power of the regressions. Similarly, the results are qualitatively the same when adding *FICO*, *TPO share*, and *refi share* as additional controls (see columns (3) and (4)) and, in fact, the coefficient on *Fed ownership* is the largest in these specifications. Not surprisingly, we find that pools with a higher credit score are more likely to prepay than worse credits, as indicated by the coefficient on *FICO*. Finally, both *TPO share* and *refi share* are positively correlated with prepayment speeds.

For the sake of brevity, we focus the discussion for all remaining coupons—that is, 5.0 - 6.5 percent coupons—on the results for the *Fed ownership* variable. In the baseline specification, the coefficient estimates on *Fed ownership* range from 2.2 to 5.3 and are highly statistically significant. The inclusion of additional controls does not render the coefficient estimates insignificant. As before, Federal Reserve-held securities exhibit significantly faster prepayment behavior, even after controlling for factors that dealers use to determine which securities to deliver into TBA contracts. In economic terms, securities held by the Federal Reserve experienced, on average, abnormal

prepayments of up to 5.3 percentage points over the period from June 2010 to June 2012. As was the case for the 4.5 percent coupon, the coefficients on various control variables, in general, carry the expected signs and are highly statistically significant. Although qualitatively the same across coupons, the coefficient estimates on the control variables vary a bit in magnitude. Finally, as indicated by the adjusted R-squared figures in the last row of the table, a significant portion of the variation in prepayment rates is explained by our regression model.

Moreover, including the share of the remaining principal balance held by the Federal Reserve rather than the *Fed ownership* dummy yields qualitatively similar results. As shown in Table 4, we obtain statistically positive coefficient estimates for *Fed share* for all coupons but the 4.0 percent coupon, which suggests that the abnormal prepayment behavior is stronger for those securities that the Federal Reserve holds in larger amounts. In the baseline specification, the estimates range from 2.8 to 6.7. Furthermore, the effect is robust to the inclusion of additional control variables in specifications (2)-(4). Importantly, even though the finding that abnormal prepayments are larger for securities held by the Federal Reserve in large amounts does not rule out the possibility that our results are due to a misspecified model, it does undermine this concern and points to a causative effect of Federal Reserve ownership. The estimated effects of various controls are very similar to those in Table 3 when *Fed ownership* is used as the explanatory variable.

As a robustness check, we pool all securities and re-run the regression model specified in equation (1). For these pooled regressions, we also include coupon-vintage dummies in some specifications. The first set of columns in Table 5 presents the estimation results when *Fed ownership* is used as the key independent variable and the second set reports the results when *Fed share* is used. As before, the estimates for the control variables have the expected sign and, in general, are statistically significant. Importantly, the relationship between Federal Reserve ownership and prepayment rates documented previously holds in the pooled regression framework.[16] The coefficient estimates on both *Fed ownership* and *Fed share* are highly statistically significant

[16]The inclusion of the 4.0 percent coupon securities attenuates the magnitude of these coefficients somewhat.

in various specifications. The size of the coefficient on *Fed ownership* in specification (4) implies that securities held by the Federal Reserve show prepayment rates that—after controlling for other factors that determine prepayment speeds—are about 3.4 percentage points higher than they would otherwise be.

Comparing the estimates from Table 5 with the prepayments from Figure 1 indicates that a substantial proportion of the total prepayment differences cannot be accounted for by the characteristics used to identify CTD MBS. Although a prepayment difference of three percentage points over the course of two years may seem relatively small, there are reasons why a more sizable measured effect may not be expected, as we will discuss in more detail below. Nevertheless, the large par amount of Federal Reserve holdings (approximately $1 trillion) implies that Federal Reserve MBS ownership is associated with roughly $30 billion of additional refinancings over this period.

4.2. Propensity Score Matching Results

According to the results presented above, the effect of Federal Reserve ownership on prepayment rates is robust to different regression specifications. Furthermore, unreported results show that the inclusion of additional interactions and control variables as well as higher powers of the control variables do not materially change the results. Nevertheless, our findings may be the result of model misspecification and nonlinearities if we are not controlling accurately for all factors that may affect prepayment behavior. Of course, the finding that prepayment speeds increase in the share of the CUSIP held by the Federal Reserve provides some remedy against this concern.

An alternative strategy to account for the likelihood that the Federal Reserve was delivered only those MBS that were CTD is to use propensity score matching (PSM). Rather than relying on a parametric model that must be correctly specified, the goal of PSM is to non-parametrically balance characteristics of different MBS. In this way, MBS held in the SOMA portfolio can be matched to securities that are very similar across characteristics used to identify CTD securities.

Propensity score matching may be particularly appealing in this instance because dealers rely on a "selection-on-observables" strategy to identify the securities used to satisfy TBA contracts.

Thus, identifying market-held securities that are also traded on a CTD basis as of June 2010 allows us to compare the prepayment outcomes of the treated (SOMA-held) MBS with the control (market-held) MBS to achieve an estimate of the causal effect of Federal Reserve ownership. Given conditions outlined in Rosenbaum and Rubin (1983), the propensity score matching estimator can be written as follows:

$$\begin{aligned} \text{ATT}^{PSM} &= \mathbb{E}\left(\text{TPR}_1|\text{SOMA}=1, Pr(\text{SOMA}=1|x)\right) \\ &\quad -\mathbb{E}\left(\text{TPR}_0|\text{SOMA}=0, Pr(\text{SOMA}{=}1|x)\right). \end{aligned} \tag{2}$$

The propensity score matching estimator can be interpreted as the average difference in prepayment rates between securities held in SOMA (TPR_1) and those held by the market (TPR_0), weighted by the propensity score distribution of delivery into the SOMA portfolio ($Pr(\text{SOMA}=1|x)$).

To generate propensity scores for each security, we estimate a probit model using security-level characteristics described in Table 2, along with a host of additional variables including indicators of production years, geographic representation, and mortgage servicers. We then use a local linear regression matching estimator to identify MBS that were not delivered to the Federal Reserve but would have also been considered CTD.[17] In this way, we are able to estimate the so-called "average treatment effect on the treated" (ATT) securities—that is, the additional prepayments on securities as a result of acquisition by the Federal Reserve—which we report in Table 6. While we do not find discernable treatment effects for the 4.0 percent and 4.5 percent coupon securities, we find highly statistically significant effects that are economically meaningful for other coupons. The strongest treatment effect is documented for the 5.5 percent coupon, and indicates that Federal Reserve ownership leads to a prepayment rate that is about 4.6 percentage points faster than it would have otherwise been.

[17]Employing a nearest neighbor matching estimator produces very similar results.

Table 6 also reports pseudo R-squared values of the probit model before and after matching, which demonstrate that adequate balancing was achieved. This is especially true for the higher coupons, which offer a richer set of control (market-held) MBS with which Federal Reserve securities can be matched. For these securities, we can be confident that the matched market-held securities are very similar to Federal Reserve-held MBS and would have also been considered CTD in June 2010. The relative dearth of market-held MBS in the 4.5 percent coupon may explain the insignificant results achieved for the ATT, though it is also likely that the young age of the loans and the high share of refinancings in these pools (see Table 2) limit the ability to detect differences between SOMA- and market-held securities.

Furthermore, we report Rosenbaum bounds to determine how strongly an unmeasured confounding variable must affect selection into treatment in order to undermine the causal effects produced by the matching analysis (Rosenbaum (2002)). For example, the observed effect for the 5.5 percent coupon would still be significant even if hidden bias resulted in SOMA-held securities being more than two times as likely to be delivered to the Federal Reserve than matched market-held securities. Since the characteristics provided by eMBS are also those used by market participants to forecast prepayment rates, this degree of hidden bias owing to unobserved variables seems unlikely. Furthermore, in unreported results, we find that extending the comparison window beyond June 2012 increases minimum Rosenbaum bounds for all coupons and shows that SOMA-held 4.5 percent coupon securities eventually began prepaying at a quicker pace than similar market-held CUSIPs.

Overall, the PSM results support the previously reported finding that higher-coupon securities held by the Federal Reserve experience substantially faster prepayment rates than comparable securities held by the market, and this difference cannot be explained by characteristics traditionally used to forecast prepayment rates.

5. Possible Explanations of the Abnormal Prepayment Rates

The previous results demonstrate that MBS purchased by the Federal Reserve exhibit abnormally fast prepayment behavior that cannot be explained by the characteristics dealers use to identify CTD securities. In this section, we discuss several possible explanations for this finding and present empirical evidence that points to a principal-agent problem in the MBS market as the most likely explanation.

5.1. Private Information

One possibility that could explain the results reported above is that lenders may obtain private information regarding borrowers' likely refinancing behavior. For this to be the case, banks would have to use this information to identify borrowers that are more likely to prepay, and sell the MBS backed by these mortgages disproportionately to the Federal Reserve. Essentially, this would amount to an omitted variable correlated with Federal Reserve ownership.

Such private information may be either "soft information" gathered through banking, lending, and servicing relationships with homeowners or other borrower characteristics that are not disclosed to other market participants (see Downing et al. (2009)). For example, Stanton and Wallace (1998) show that borrowers' points-mortgage rate choice allows lenders to separate borrowers into those that are likely to prepay and those that are not.

To rule out this potential explanation for our results, we identify a subset of MBS for which lenders are unlikely to possess private information that would not be captured by characteristics detailed in eMBS, and run a similar set of regressions. Observing similar results to those reported for the full sample would indicate that the possession of private information cannot explain the results achieved above.

Table 7 presents an identical set of regressions to those included in Table 5, but limits the sample to those MBS for which third party originations compose more than 50 percent of the underlying mortgages. We note that such originations include those by correspondent lenders, which, like any originator, may obtain private information through the direct relationship with

the borrower that may then be used to identify borrowers who are more likely to prepay. However, correspondent lenders typically close and finance their own loans (Cleary (2008)), and may also continue to service the mortgages (Brueggeman and Fisher (1997)). Consequently, much of the private information—which comprises both characteristics of the loan such as points paid upfront and information acquired through banking, lending, and servicing relationships—would be shielded from the institution that ultimately purchases the mortgages prior to securitization. If private information was indeed used to deliver securities to the Federal Reserve, the coefficient on *Fed ownership* and *Fed share* should be very small or insignificant for the subset of MBS for which the share of third party origination is greater than 50 percent. However, as shown in Table 7, *Fed ownership* and *Fed share* maintain their explanatory power for TPR. Thus, it seems that private information acquired through an origination and lending relationship is unable to explain the abnormal prepayment behavior of SOMA-held MBS.

5.2. Bundling of Whole Loans

Another possible explanation of the anomalous prepayment behavior documented above is that banks selected from their whole loan portfolio to create new MBS that were then delivered to the Federal Reserve. This could have occurred in response to the very high MBS demand engendered by QE1. If the new securities exhibited higher prepayment rates and our regressions above do not adequately capture drivers of prepayment speeds (perhaps because selection is at the individual loan level), we could incorrectly identify a significant effect of Federal Reserve ownership as a result.

In order to test for this possibility, we split our original sample into MBS issued during the course of QE1 (2009 and 2010) and MBS issued prior to QE1. If selection of whole loans for delivery to the Federal Reserve were the cause of the unexplained prepayment differentials, we would expect that MBS issued in 2009 or later drive the results. However, as shown in Table 8, we find significant effects for MBS produced prior to the commencement of QE1. Similarly, Table 9, shows the results for production years 2009 and 2010, while QE1 was ongoing. The effect of

Federal Reserve ownership persists for these securities, but is slightly weaker than for the rest of the sample. Thus, we can rule out the possibility that it is the selection from banks' whole loan portfolios during the purchase program that drives the results reported in Section 4.

5.3. Delinquency Rates

There is also the possibility that the abnormal prepayment behavior of MBS held by the Federal Reserve is driven by higher rates of delinquency and default, which may not be fully captured by, for instance, geographic controls, credit scores, and loan-to-value ratios. In this case, higher prepayment rates on securities delivered to the Federal Reserve could merely reflect involuntary prepayment behavior resulting from excessive delinquencies. We note, however, that the results reported above for securities produced in 2009 and 2010 suggest that the higher prepayments on securities held by the Federal Reserve are not due to delinquencies. Given the tight lending standards during this period, the stable house prices, and the relatively short time period used to calculate the total prepayment rate, delinquencies for these securities over our observation period were likely minimal. Consequently, observing an effect for Federal Reserve ownership for this subsample suggests that voluntary prepayments are in fact driving the result.

Nevertheless, we are able to account for the effect of delinquency-driven prepayment behavior more directly. Although only available for MBS issued by Freddie Mac, eMBS contains monthly figures for the share of prepayments that are due to agency repurchases of delinquent loans. Thus, we remove these involuntary prepayments from the total prepayment rate, and regress this value on our standard set of controls for Freddie Mac securities. Table 10 presents the results for total prepayment rates that are purged of delinquency repurchases. As evidenced by the positive and statistically significant coefficient estimates for both *Fed share* and *Fed ownership*, higher rates of involuntary prepayments cannot explain the abnormally high prepayment behavior of MBS owned by the Federal Reserve. Similarly, in unreported results, we find that including the share of each MBS that is backed by mortgages that are between 30 and 90 days past-due does not affect these results.

5.4. An Agency Problem in the Secondary MBS Market

Finally, the above result may be explained by a principal-agent problem that is present in the secondary MBS market more generally. This agency problem can arise when an institution that originated the mortgages underlying an MBS no longer bears the prepayment risk of the security. Having transferred the prepayment risk to an outside investor (the principal), the originating institution (the agent) may wish to refinance mortgages it originated in order to generate income from refinancing fees.[18] In fact, an analogous agency problem is often cited to explain the otherwise puzzling prepayment behavior exhibited by mortgages that are originated by third parties such as mortgage brokers (see, for example, LaCour-Little and Chun (1999)). These incentives are so pervasive that non-solicitation agreements are commonly included to protect lenders from the potential agency problem. However, investors (such as the Federal Reserve) simply purchase MBS in the secondary market, and thus no such non-solicitation agreement could exist.[19] Insulated from the prepayment risk, a bank faces incentives to encourage a higher rate of refinancing activity subsequent to selling MBS. Because banks hold a substantial fraction of MBS outstanding, comparing the Federal Reserve's MBS portfolio with that of the market as we have done here, can reveal a significant difference in prepayment rates that would not be explained by the MBS characteristics alone if this mechanism were in operation.

Notably, this mechanism would represent an important feature of the secondary market for MBS, because all MBS investors that purchase securities from originators face this agency risk by altering incentives as described above. Indeed, our conversations with staff at large mortgage originators and servicers suggest that this agency issue is widespread. Yet, to the best of the authors' knowledge, this agency problem has remained undocumented in the literature. In the

[18] Of course, originators may still be exposed to prepayment through a mortgage servicing right (MSR) asset. However, if the refinancing is solicited by the originator/servicer, the MSR will simply be replaced with a more valuable MSR. This difference in value arises because servicing assets are required to be reported at fair value, and servicing fees accrue over longer periods for mortgages with lower interest rates.

[19] We would note that because a goal of QE is to boost economic activity, the Federal Reserve would be unlikely to desire such an agreement even though it would reduce the negative convexity risk of the SOMA portfolio. This is because increased refinancing activity is typically assumed to be stimulative (see Fuster and Willen (2010) and the references therein.)

remainder of this section, we present evidence that is consistent with an agency problem in the secondary market for MBS.

First, we note that the smaller or non-existent effects associated with Federal Reserve ownership of lower-coupon MBS (presented in Tables 3, 4, and 6) are consistent with the agency problem. If solicited refinancing activity can explain differential prepayment rates for investor-owned MBS, there should be no discernable difference for securities backed by loans with prepayment options that are not sufficiently in the money. For borrowers with relatively low-rate mortgages, savings from refinancing would be either nonexistent or too small to justify incurring the upfront fees. As interest rates fall, however, mortgage originators will begin soliciting mortgage refinancings, with a bias towards loans underlying MBS that the bank no longer holds. Consistent with this narrative, the null result observed for the 4.5 percent coupon in Table 6 becomes positive and statistically significant when the prepayment horizon is extended by one year to include more of the very low interest rate period that prevailed around the announcement of the third QE program.

A second important prediction of the agency problem mechanism described above is that the estimated effect of Federal Reserve ownership on total prepayment rates would not steadily increase over time. Rather, banks would focus first on soliciting refinancings among the set of borrowers that would benefit from such a transaction and whose securitized mortgages it no longer holds. Eventually, though, banks would exhaust this set of borrowers and monthly prepayment rates would be more similar between SOMA-held and bank-held securities (conditional on $\boldsymbol{x_i}$). Potentially, resources may then be used to refinance homeowners whose mortgages securitize MBS held by the bank, leading to a tapering of the documented effect.

In contrast, if the documented effect was the result of model misspecification or omitted variable bias—that is, if the CTD features of MBS held by the Federal Reserve are not properly accounted for—then the perpetually higher prepayment risk of securities held by the Federal Reserve would imply that these securities prepay more than market-held securities each month

and, consequently, the size of the observed effect would grow continuously over time.[20] Thus, we run the pooled regressions outlined previously for different sample periods that extend beyond our baseline sample. That is, we keep the start date for the sample the same but extend the end date in increments of six months until the end of 2013. Figure 2 depicts the leveling-off of the effect over time. As shown in Panel (a), the estimated effect of *Fed ownership* on prepayment rates increases as the end date of the sample period is extended gradually from the second quarter 2011 to the end of 2012 but then tapers off. Analogously, Panel (b) presents the coefficient estimates on *Fed share*. The evolution of the effect is the same as that for *Fed ownership* depicted in Panel (a). Ultimately, this exercise supports the notion that the effect of abnormal prepayment behavior of Federal Reserve-held securities is likely due to an agency problem and not the result of improperly or inadequately accounting for CTD features of MBS acquired by the Federal Reserve.

Another implication of the agency problem mechanism, which can explain the observed prepayment differential between Federal Reserve- and market-held MBS, is that this mechanism would likely be strongest for large institutions. These institutions originate the majority of the loans and hold a significant amount of the securitized loans on their balance sheets. Therefore, large originators have a greater incentive to incur the fixed costs of identifying which mortgages back which MBS, and will devote resources accordingly. In other words, larger institutions have both the incentives and the ability to preferentially solicit refinancings from borrowers whose prepayment risk has been transferred from their balance sheets to the Federal Reserve.

To test for differential effects between large and small institutions, we would ideally include originator information in the pooled regressions. While our dataset contains only limited data on loan originators, it furnishes information about the servicers of the loans. Using the plausible assumption that the four largest banks, which originated most of the mortgages in the United States, service many of the originated loans, we can exploit servicer information to draw inference on differential effects for large and small originators. To that end, we include dummy variables

[20] It is possible that a burnout effect could lead to a tapering of the measured effect as implied by the agency problem described above. However, the securities held by the Federal Reserve are relatively unseasoned (see Table 1), and the documented effect is therefore unlikely a result of burnout.

for the four largest U.S. bank holding companies (Bank of America, Citigroup, J.P. Morgan, and Wells Fargo) that equal one if a bank services the plurality of the mortgages in a pool and zero otherwise, as well as interactions of these dummies with *Fed ownership* and *Fed share*, respectively. These four banks are the dominant servicers in nearly 60 percent of the MBS in our sample. Table 11 reports the results for various regression specifications using *Fed ownership* on the left, and the results using *Fed share* on the right. As before, the coefficient estimates on *Fed ownership* and *Fed share* are highly statistically significant, indicating that the agency problem mechanism exists in medium- to smaller-sized originators.

In both sets of results, the coefficient estimates on the large-bank dummy variables support the well-known fact that refinancing activity at Bank of America and Citigroup was more muted over this period; in contrast, J.P. Morgan and Wells Fargo refinanced more mortgages compared to other institutions. Moreover, the stark differences in prepayment rates for different servicers illustrate the ability of institutions to influence refinancing activity among their borrowers. Finally, in the specifications in which *Fed ownership* is used, the coefficients on the interaction terms suggest that the abnormal prepayment rates as a result of Federal Reserve ownership is even more pronounced for the four largest banks. This effect is strongest for pools serviced by Wells Fargo. Interestingly, this result holds even for securities serviced by Bank of America that generally prepaid more slowly. It seems plausible that in light of capacity constraints over this period, any refinancing initiatives may have focused on securities no longer held by the bank. When *Fed share* is used, this effect remains evident, although the results are slightly weaker for Bank of America and Citigroup. In total, these results suggest that, although the channel is in effect for firms of all sizes, abnormally fast prepayment rates are even more pronounced among larger originators, a finding consistent with an explanation that an agency problem mechanism is at work.

To test a final implication of this mechanism, we note that if selling MBS generates an agency problem wherein mortgage originators are more likely to solicit refinancings from loans they no longer own, this pattern should also be evident at the individual mortgage level. Observ-

ing a similar pattern to that demonstrated at the MBS level would mitigate concerns that the result is driven by the nature of QE1 purchases or the specifics of TBA trading more generally. Although we are unable to identify which mortgages are sold out of originators' portfolios, the Lender Processing Services (LPS)/McDash Analytics data (now Black Knight Data & Analytics) provide mortgage-level information on borrowers, loan terms, securitization status, and reason for termination. Thus, we can compare refinancing behavior for mortgages that are held outright in whole loan portfolios against those that have been securitized to provide corroborating evidence of an agency problem. Since securitized mortgages are far more likely to be sold out of originators portfolios, observing higher prepayment rates among otherwise identical securitized mortgages would be consistent with the operation of an agency problem arising when originators no longer share in the prepayment risk of the mortgage.

Controlling for observable differences between retained and securitized mortgages is highly important since, as Agarwal et al. (2012) show, adverse selection is present in mortgage securitization as banks may prefer to hold loans in their whole loan portfolios that are likely to prepay more slowly. Thus, in order to investigate differences in refinancing rates at the loan level, we conduct a propensity score matching analysis on a 5-percent sample of active mortgages (as of June 2010) from LPS. From this sample of mortgages, we keep only conventional 30-year, fixed-rate, full-documentation loans extended for the purchase of single-family primary residences. Applying these filters and keeping only conforming mortgages (using the same algorithm as Agarwal et al. (2012)) yields a monthly panel of 47,040 mortgages. Next, we match loans that are held in whole loan portfolios with securitized loans by balancing across the following characteristics: borrower credit score, loan-to-value ratio, borrower debt-to-income ratio, home appraisal amount, original loan amount, monthly principal and interest payment, remaining loan term, interest rate, remaining principal balance, jumbo status, and state of residence. Conventional balancing tests (not shown) all indicate that mortgages are adequately balanced across observables.

Figure 3 plots the difference in the share of refinancings between securitized loans and portfolio-held loans at various horizons. For example, 10.2% of unsecuritized loans refinanced by

June 2011, whereas 15.1% of the matched securitized loans refinanced, for a net difference (ATT) of 4.9%. By June 2012, 18.3% of unsecuritized loans refinanced compared with 28.6% of similar securitized loans. As demonstrated in Figure 3, the average effect of securitization reached as much as 18.8% for the December 2013 horizon, by which point 32.7% of unsecuritized loans and 51.5% of matched securitized loans refinanced. Because some of the securitized mortgages may remain on originators' balance sheets, these figures would likely be even larger if it were possible to compare only those securitized loans that were sold to other MBS investors.

Despite the lack of data on which securitized loans are sold, it is possible to additionally consider mortgages that are more likely to be sold to third party MBS investors. Specifically, mortgages securitized by Ginnie Mae are particularly attractive to certain MBS investors because of their lower prepayment rates and explicit government guarantee. In fact, many potential MBS investors are limited to Ginnie Mae securities by prospectus, law, or self-imposed guidelines. Thus, we should expect to see higher rates of securitization than we observe for the conventional mortgages considered above. Indeed, this is precisely what we observe in the LPS data: 93% of conventional mortgages in our sample are securitized, compared with over 98% of the Federal Housing Authority (FHA) and U.S. Department of Veterans Affairs (VA) loans in our sample. In Table 12, we compare rates of refinancing between conventional mortgages and FHA/VA mortgages over several time periods. Panel A of Table 12 reports the share of conventional unsecuritized and securitized mortgage loans that refinanced in the first two columns. As detailed in the third column (and plotted in Figure 3), the incidence of refinancing is consistently higher for mortgages held outright in whole-loan portfolios when compared with matched securitized loans. Similarly, Panel B of Table 12 reports the same statistics for a sample limited to FHA and VA loans that are either held in whole-loan portfolios or securitized into Ginnie Mae-issued MBS. As in Panel A, the matched securitized mortgages exhibit significantly higher refinancing rates, and when the difference is measured in either absolute terms or as a percent of the securitized refinancing rate (column 4), the effect of securitization is stronger for Ginnie Mae securities.

Thus, these loan-level results are consistent with an agency problem that generates an additional source of refinancing activity for loans that are no longer held by originators.

Finally, it is understandable that the magnitude of an effect owing to this agency problem would be relatively modest. First, to the extent that some MBS purchased by the Federal Reserve were not held by the originator shortly before QE1 purchases occurred, we would not expect a causative effect of Federal Reserve MBS ownership since the agency problem arises whenever MBS are transferred to any outside investor. Second, if MBS are held in different business units than the sales and mortgage origination divisions, it may be difficult for banks to identify which mortgages secure MBS held by the bank. Both of these factors could contribute to a more modest size of the effect of Federal Reserve ownership on MBS prepayment rates.

6. The Solicited Refinancing Channel of Large-Scale Asset Purchases

The existence of the agency problem in the MBS market described in the previous section can generate a "solicited refinancing channel" through which LSAPs may work. If the Federal Reserve's MBS purchases reduce originators' holdings of MBS, then these institutions would have a greater incentive to solicit refinancings among the mortgages backing the MBS they no longer hold. As banks respond to these incentives, homeowners realize savings on monthly mortgage payments as a result of refinancing activity that would not have otherwise occurred.[21] The savings realized by homeowners on their monthly mortgage payments are typically assumed to have stimulative economic effects by boosting consumer spending (see, for example, Canner et al. (2002)). The savings for homeowners as a result of the additional prepayment effect documented in this study are likely a non-negligible factor in providing stimulus for the economy through increased consumer spending or a more rapid improvement in household finances. Of course, the magnitude of the increase in consumption additionally depends on refinancers' marginal propensity to consume out of monthly savings on mortgage payments and the incidence of cash-out refinancing.

[21] Similarly, savings would be generated even if these incentives simply resulted in refinancings that occurred earlier than they would have if banks continued to hold the MBS on their balance sheets.

We take two approaches to estimate the amount of refinancing activity realized as a result of this channel. In each case, we must first estimate the reduction in banks' MBS holdings as a consequence of Federal Reserve MBS purchases. First, we follow the methodology in Carpenter et al. (2015) and estimate various specifications of the following equation:

$$\Delta \text{MBS}_t \quad = \quad \theta + \phi \Delta \text{Fed MBS}_t + \boldsymbol{\psi'} \boldsymbol{x_t} + \varepsilon_t, \tag{3}$$

In equation (3), ΔMBS_t denotes the change in banks' MBS holdings for month t, and $\Delta \text{Fed MBS}_t$ captures the monthly change in Federal Reserve MBS holdings. Thus, the parameter ϕ measures the sensitivity of banks' MBS holdings to Federal Reserve MBS holdings. The vector $\boldsymbol{x_t}$ denotes control variables, which include the lagged difference of the stock of outstanding 30-year Fannie Mae and Freddie Mac MBS and one lag of the dependent variable. In other specifications, $\boldsymbol{x_t}$ additionally includes three controls for changes within the banking sector—the lagged differences of system-wide assets, capital, and real estate loans—as well as three controls for broader economic and financial market conditions—the lagged value of the St. Louis Fed financial stress index, lagged industrial production growth, and the change in Treasury notes and bonds outstanding net of Federal Reserve holdings. To capture the potential for calendar-related changes in MBS holdings due to financial reporting requirements or other factors generating seasonality in the series, we also include monthly fixed effects in $\boldsymbol{x_t}$.[22]

Table 13 reports the results from the estimation of equation (3). In Table 13, the first three columns report the results using the full sample period of January 1997 through June 2014. In the first column, the coefficient on Federal Reserve MBS holdings indicates an additional dollar of Federal Reserve MBS holdings is associated with a contemporaneous 8-cent decline in banks' MBS holdings. However, the absolute value of this coefficient could be biased down for several reasons. For instance, banks could respond to the higher demand for MBS by securitizing more

[22]Banks' MBS holdings correspond to the data series published in the Federal Reserve's statistical release H.8. Note that for the period prior to July 2009, the series is not publicly available. The stock of outstanding MBS is obtained from eMBS and the stock of outstanding Treasury notes and bonds held by the public is published in the U.S. Treasury's "Monthly Statement of the Public Debt of the United States." All other series are made available by the Federal Reserve Bank of St. Louis through the Federal Reserve Economic Data (FRED) repository.

of their whole loans, or Federal Reserve MBS purchases could improve financial conditions more broadly, increasing banks' willingness to expand their MBS portfolios. In order to control for such effects, columns (2) and (3) include the additional covariates previously outlined. In these specifications, the response of banks' MBS holdings to Federal Reserve purchases is about twice as strong. Though the banking-system controls exhibit no statistically significant association with changes in MBS holdings, the economic and financial market controls are generally significant.

Of course, the Federal Reserve did not maintain MBS holdings until the beginning of QE1 in early 2009. Thus, the second set of specifications in Table 13 limits the sample to the months after the start of Federal Reserve MBS purchases and settlements in January 2009. In these specifications, we observe a similar downward bias of ϕ in the most basic specification. The coefficient of -0.31 reported in the richest specification (the final column of Table 13), implies that the Federal Reserve's $1.25 trillion of MBS purchases during QE1 reduced banks' MBS holdings by approximately $390 billion.[23] Using the estimate from Table 5 that total prepayment rates on SOMA-held MBS were approximately four percentage points higher than on market-held MBS suggests that QE1 generated about $16 billion in additional refinancing activity over a two-year period.

As a second approach to estimate the amount of refinancing activity realized as a result of the QE1 solicited refinancing channel, we gauge the reduction in banks' MBS holdings by summing out-of-sample forecast errors during QE1. Below, we report coefficient estimates and robust standard errors (in parentheses) for a prediction of banks' MBS holdings estimated for the ten years from January 1997 to December 2006:

$$\begin{aligned}\Delta\text{MBS}_t \;=\; & \underset{(0.08)}{0.13}\cdot\Delta\text{MBS}_{t-1} + \underset{(0.04)}{0.03}\cdot\Delta\text{assets}_{t-1} + \underset{(0.22)}{0.33}\cdot\Delta\text{capital}_{t-1} + \underset{(0.18)}{0.01}\cdot\Delta\text{RE loans}_{t-1} \\ & + \underset{(4.11)}{8.01}\cdot\text{stress}_{t-1} + \underset{(2.91)}{8.41}\cdot\text{IP growth}_{t-1} + \underset{(0.06)}{0.13}\cdot\Delta\text{Treas outstanding}_t \\ & + \underset{(0.21)}{0.49}\cdot\Delta\text{MBS outstanding}_{t-1} + \boldsymbol{\gamma'M_{1-12}} + \varepsilon_t. \qquad (4)\end{aligned}$$

$$\text{N} = 120;\ \text{R-squared} = 0.24;\ \text{DW stat} = 1.98.$$

[23] We ignore the lagged dependent variable for this calculation as it is not statistically different from zero.

Equation (4) corresponds to the final specification from the previous exercise, with the exception of the variable ΔFed MBS$_t$, as Federal Reserve MBS holdings simply equal zero for all months prior to 2009. Next, we use equation (4) to predict MBS holdings for the 18-month period during which QE1 MBS were delivered to the Federal Reserve. Figure 4 plots actual changes in banks' MBS holdings versus the predicted values for the QE1 period of January 2009 through June 2010. The predicted change in banks' MBS holdings was frequently greater than the actual change during QE1, though this pattern dissipated somewhat toward the end of the program as the Desk gradually reduced MBS purchase amounts. Nevertheless, actual increases in banks' MBS holdings were greater than predicted in only two months during QE1, and in total, banks' actual MBS holdings were approximately $425 billion lower than predicted. Assuming that the Federal Reserve's MBS purchases caused this deviation in MBS holdings, and again using the result that prepayment rates attributable to solicited refinancings were four percentage points higher implies that QE1 MBS purchases generated about $17 billion in additional refinancing activity over a two-year period—very close to the previous estimate of $16 billion.

However, the $16-$17 billion estimate likely understates total refinancing activity as a result of this channel, since the difference in prepayment rates reported in Table 5 is achieved by comparing SOMA-held securities to *all* other similar CUSIPs rather than just the subset held by banks. Including the holdings of other MBS investors (such as asset managers or foreign central banks) in the comparison cohort produces a downward bias of the estimated effect of Federal Reserve ownership, since these securities are subject to the same agency problem as those held by the Federal Reserve. In addition, subsequent Federal Reserve MBS purchases—such as those associated with the MBS purchases of QE3—would have generated additional refinancings and savings for homeowners as a result of this channel. We note that, since 2009, the Federal Reserve has purchased over $3 trillion of MBS.

Importantly, the refinancings that are produced by the solicited refinancing channel are *in addition* to those that occur simply as a result of the decline in interest rates *per se*, which could follow a QE-induced fall in interest rates regardless of the type of assets purchased under

the program. Rather, the solicited refinancing channel arises because originators act as agents of MBS investors such as the Federal Reserve, and can influence prepayment rates through borrower outreach. Indeed, because there can be potentially important differences in the effects of central bank purchases depending on the type of asset purchased, many economists refer to these programs as LSAPs rather than QE, since QE has traditionally been used to describe an expansion of a central bank's liabilities with little consideration for the composition of purchased assets (Bernanke (2009)).

7. Conclusion

In this paper, we show that Federal Reserve-held MBS prepay significantly faster than MBS not held by the Federal Reserve. We then show that much of the prepayment differences cannot be explained by factors that are used by dealers to determine the cheapest-to-deliver securities sold to the Federal Reserve.

We assess four possible explanations for the difference in prepayment rates between SOMA- and market-held MBS that is not accounted for by "cheapest-to-deliver" characteristics of the securities: 1) dealers may determine which securities to deliver based, in part, on private information obtained through their lending relationships with the borrowers; 2) banks may have selected loans with very high prepayment risk from their whole loan portfolio to create new MBS that could be delivered to the Federal Reserve; 3) dealers may have delivered securities that suffered from higher rates of delinquency and involuntary prepayments; and 4) an agency problem that arises because institutions that originated the mortgages backing a security no longer share in the prepayment risk of that security after it is purchased by the Federal Reserve, which will incentivize originators to refinance the underlying mortgages.

Our test results point to the agency problem mechanism as the most likely explanation for the abnormal prepayment behavior of Federal Reserve-held MBS. Although this agency problem is an important feature of the secondary market for MBS, it has hitherto gone undocumented in the literature. We also explain that the presence of this agency problem can result in a so-called

"solicited refinancing channel" of large-scale MBS purchases by the Federal Reserve that can generate substantial refinancing activity. Higher prepayment rates as a result of Federal Reserve MBS ownership, in conjunction with a QE1-induced decrease in mortgage rates, lead to savings for borrowers on their monthly mortgage payments, which can improve household finances by reducing debt-service burdens. Although modest compared with previously documented channels of QE, with large enough MBS purchases, the solicited refinancing channel can have non-negligible stimulative effects for the economy.

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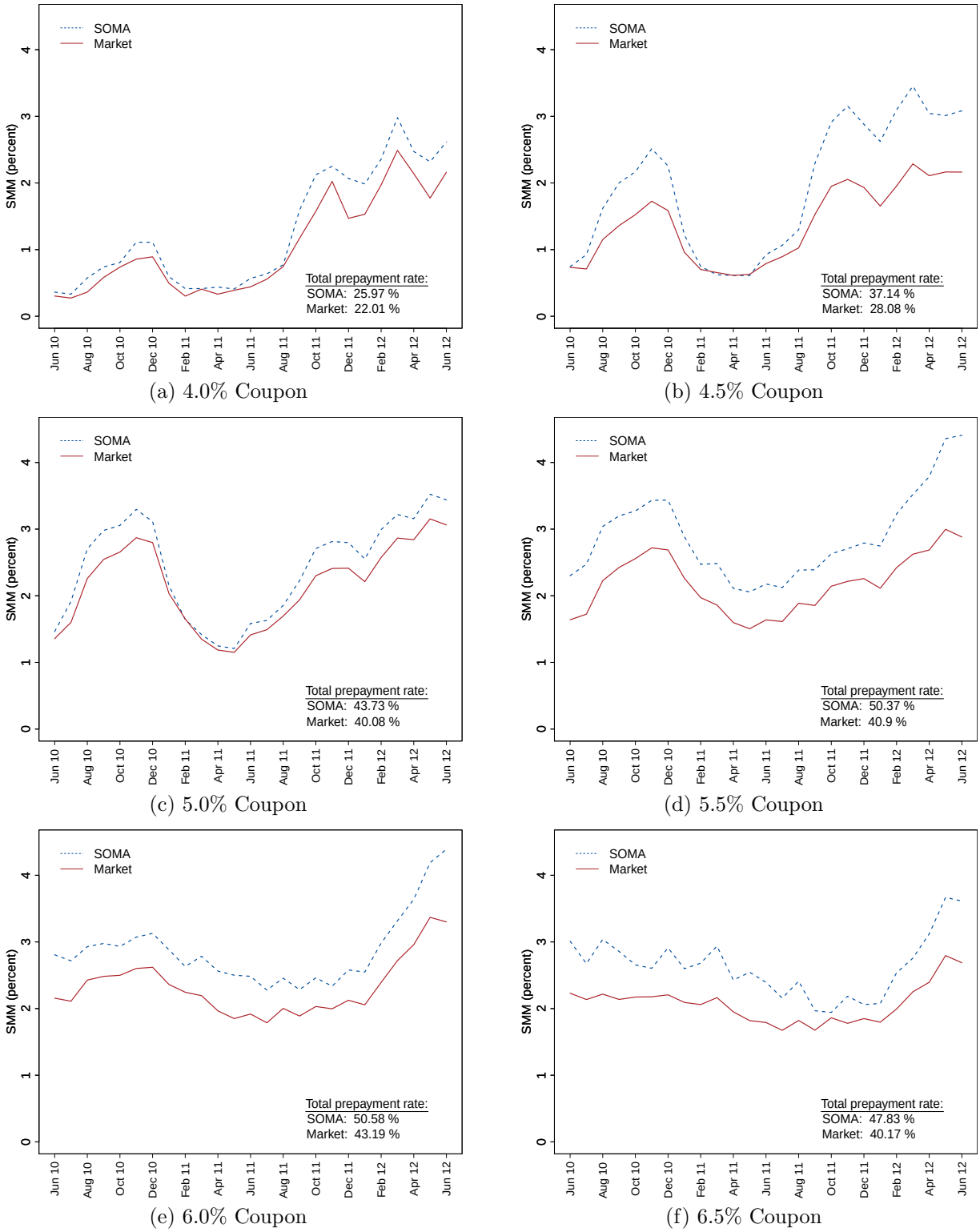
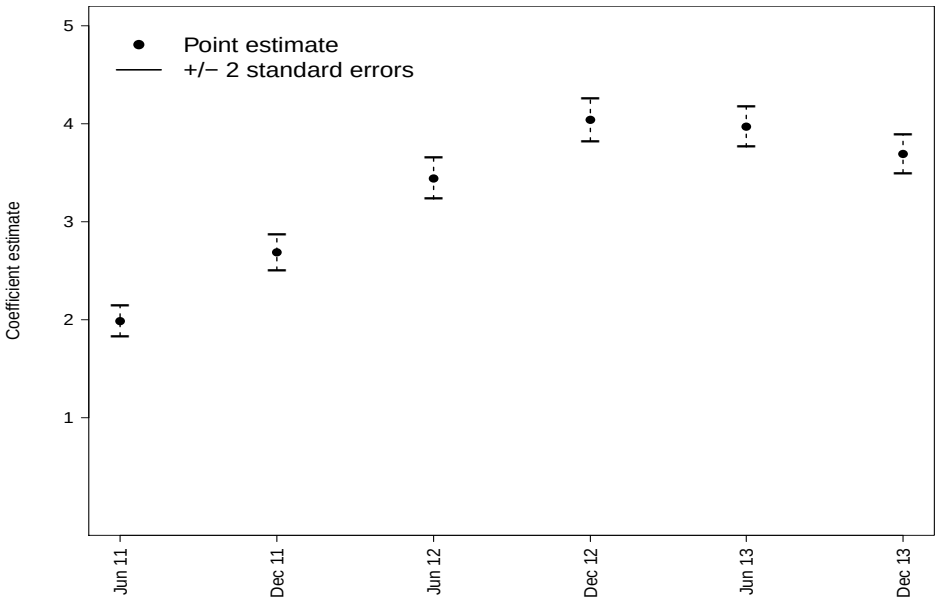


(a) 4.0% Coupon (b) 4.5% Coupon

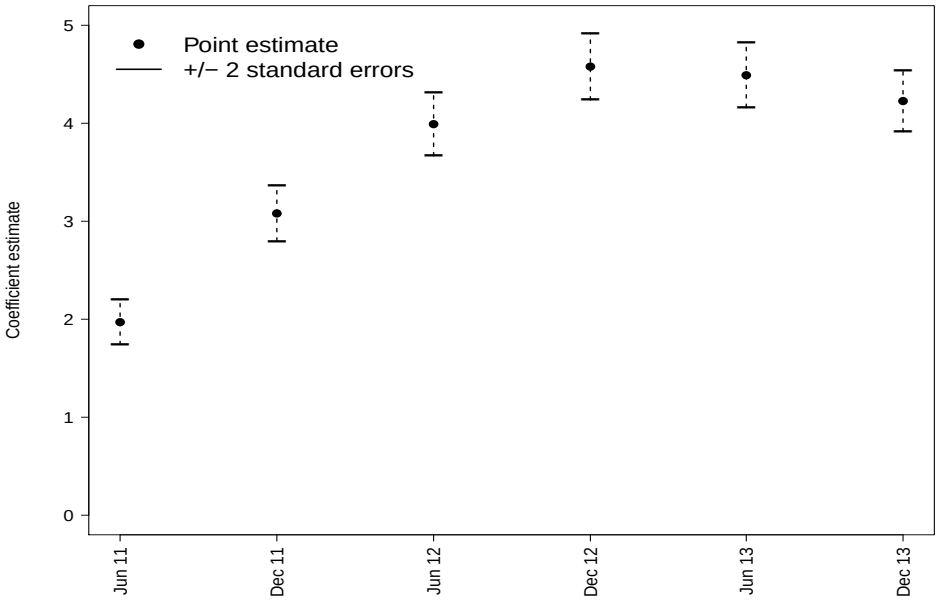
(c) 5.0% Coupon (d) 5.5% Coupon

(e) 6.0% Coupon (f) 6.5% Coupon

Figure 1. Prepayment Rates of Fannie Mae and Freddie Mac 30-Year MBS. This figure plots monthly prepayment rates (single monthly mortality rates) for each coupon. The blue dashed line represents average prepayment rates across all Fannie Mae and Freddie Mac 30-year securities held by the Federal Reserve in the System Open Market Account (SOMA). The red solid line represents the analogous prepayment rates across securities that are not held by the Federal Reserve. The total prepayment rates—computed as the amount of prepayments over the period 06/2010-06/2012 divided by the remaining principal balance as of 06/2010— for the two sets of securities are reported in the bottom right of each panel. Older vintages and MBS with prefix identifiers not purchased by the Federal Reserve have been dropped in order to remove securities likely to trade in the specified pool market. Source: eMBS Inc. and Federal Reserve Bank of New York.



(a) Federal Reserve ownership



(b) Federal Reserve ownership share

Figure 2. Coefficient Estimates for Different Subsamples. This figure plots OLS coefficient point estimates of *Fed ownership* and *Fed share* in Panels (a) and (b), respectively, along with a confidence interval of +/- two standard errors. Each point represents the coefficient estimate over the sample from 06/2010 to the date indicated on the x-axis. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve and *Fed share* denotes the share of security i that the Federal Reserve holds.

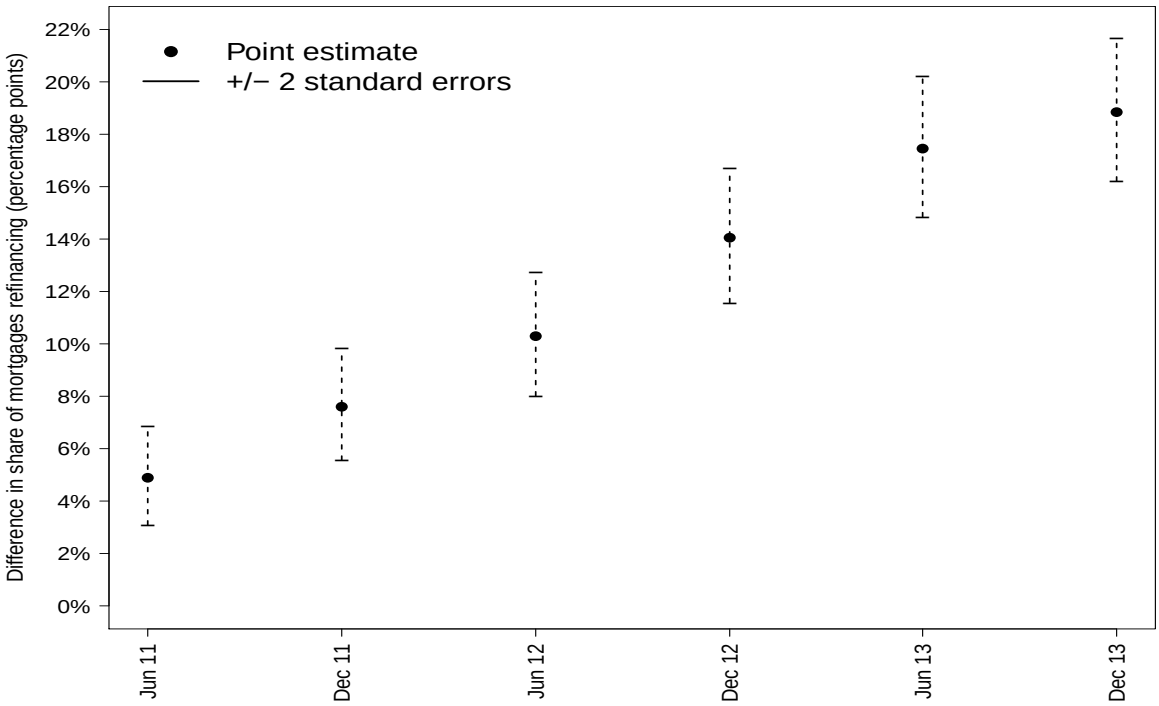


Figure 3. Propensity score matching estimates of the average effect of securitization on mortgage refinancing rates. This figure plots propensity score matching estimates of the average effect of securitization on mortgage refinancing rates, along with a confidence interval of +/- two standard errors. Each point represents the estimated effect over the sample from June 2010 to the date indicated on the x-axis.

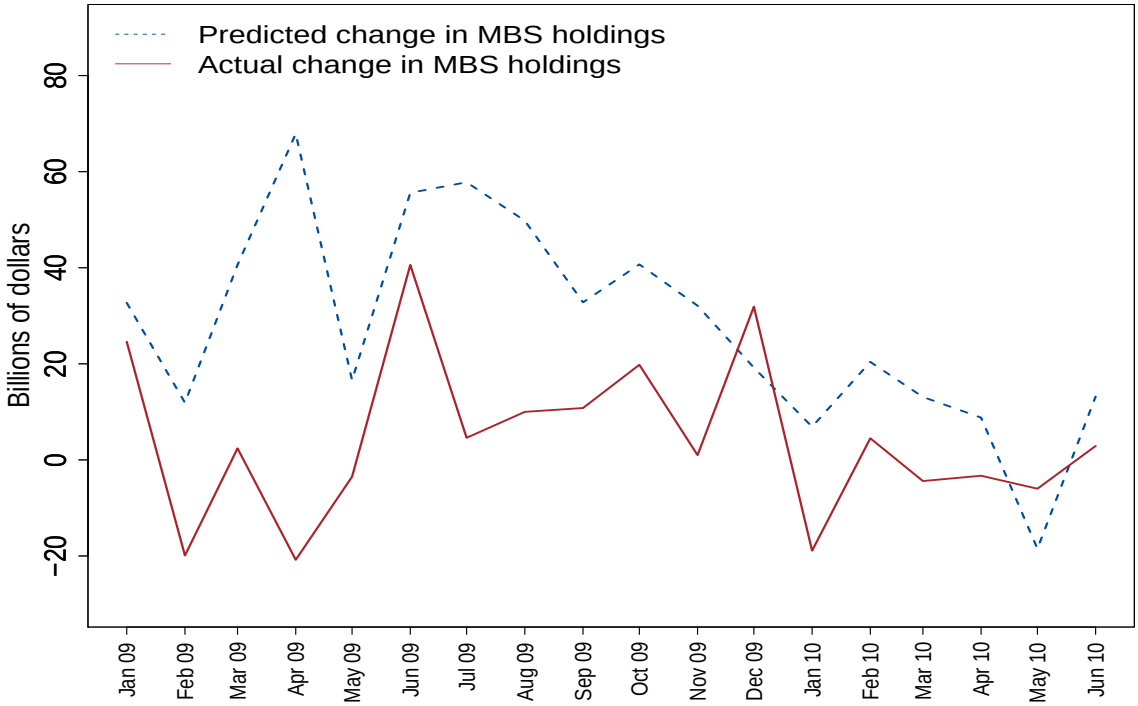


Figure 4. MBS Holdings Predictions. This figure plots actual changes in bank MBS holdings versus the predicted values for the QE1 period of January 2009 through June 2010.

Table 1
Operations Summary

Coupon distribution	
3.5	0.03%
4.0	15.23%
4.5	46.30%
5.0	24.09%
5.5	12.33%
6.0 - 6.5	2.02%
Agency distribution	
Fannie Mae	56.15%
Freddie Mac	34.72%
Ginnie Mae I	6.86%
Ginnie Mae II	2.28%
Term distribution	
15-year	3.42%
30-year	96.42%

Note: This table provides a summary of the MBS operations conducted over the period 1/5/2009-3/31/2010 as part of LSAP1. Source: Federal Reserve Bank of New York.

Table 2
Descriptive Statistics (as of June 2010)

	4.0% Coupon		4.5% Coupon		5.0% Coupon		5.5% Coupon		6.0% Coupon		6.5% Coupon	
	SOMA	Market	SOMA	Market	SOMA	Market	SOMA	Market	SOMA	Market	SOMA	Market
# of CUSIPS	1,703	336	5,125	2,695	5,556	8,447	5,879	29,087	2,689	15,075	567	7,376
Fed share	0.84	—	0.81	—	0.55	—	0.35	—	0.18	—	0.13	—
	(0.29)	—	(0.32)	—	(0.40)	—	(0.36)	—	(0.26)	—	(0.24)	—
Loan age	12.04†	8.88	12.99†	18.52	23.75†	40.23	37.45†	59.88	32.56†	37.18	34.28†	37.02
	(3.11)	(4.60)	(11.21)	(20.20)	(17.61)	(22.88)	(17.59)	(21.72)	(9.01)	(9.98)	(8.94)	(9.39)
Coupon	4.56	4.55	4.99†	5.02	5.56†	5.58	6.07†	5.99	6.56†	6.54	7.05†	7.02
	(0.15)	(0.13)	(0.14)	(0.17)	(0.18)	(0.17)	(0.16)	(0.15)	(0.16)	(0.15)	(0.21)	(0.19)
FICO	765.28	765.20	755.34	755.77	733.27†	729.63	719.48†	715.56	707.99	708.63	693.76	695.32
	(9.21)	(10.18)	(13.12)	(15.78)	(18.75)	(20.68)	(21.56)	(21.37)	(25.69)	(23.00)	(30.93)	(28.32)
Loan-to-value	66.79†	65.49	71.27†	67.77	73.58†	71.81	74.10†	73.35	76.80†	76.27	78.92†	79.82
	(5.47)	(6.58)	(5.61)	(6.79)	(6.98)	(6.68)	(7.03)	(7.39)	(7.68)	(8.25)	(7.31)	(8.03)
Loan size	231†	200	232†	137	207†	157	188†	136	196†	142	166†	125
($ thousands)	(53)	(74)	(60)	(71)	(65)	(68)	(71)	(62)	(60)	(69)	(72)	(61)
Factor	0.97†	0.98	0.94†	0.91	0.79†	0.70	0.56†	0.49	0.51†	0.56	0.45†	0.53
	(0.02)	(0.02)	(0.08)	(0.12)	(0.16)	(0.18)	(0.14)	(0.18)	(0.11)	(0.13)	(0.12)	(0.15)
Issue amount	108	82	125†	64	125†	56	184†	49	123†	49	124†	32
($ millions)	(303)	(204)	(424)	(281)	(520)	(190)	(714)	(167)	(448)	(122)	(450)	(79)
# of loans	449†	946	1,396†	2,385	15,865	12,781	44,374†	11,450	11,169†	6,953	11,457†	2,917
	(1,312)	(4,542)	(8,896)	(12,606)	(96,817)	(83,483)	(192,751)	(92,059)	(78,027)	(55,284)	(44,654)	(22,678)
TPO share	39.16†	45.50	40.34†	37.30	36.16†	25.17	31.51†	16.41	37.18†	43.38	40.52	42.49
	(33.32)	(32.56)	(35.99)	(31.68)	(34.80)	(33.19)	(36.08)	(30.41)	(38.16)	(36.56)	(38.01)	(38.91)
Max. loan size	529†	465	539†	268	497†	342	470†	277	457†	280	450†	254
($ thousands)	(171)	(230)	(176)	(215)	(176)	(194)	(159)	(170)	(137)	(190)	(156)	(177)
Refi share	82.03†	74.99	73.43†	64.62	61.45†	55.72	52.22†	56.31	47.42†	46.43	48.39†	44.04
	(15.27)	(18.88)	(19.98)	(19.64)	(20.48)	(18.46)	(20.34)	(20.15)	(20.69)	(18.91)	(18.42)	(18.89)
Freddie indicator	0.36†	0.51	0.34†	0.51	0.26†	0.55	0.15†	0.46	0.06†	0.54	0.24†	0.43

Note: This table provides for each coupon the average and, in parentheses, the standard deviation of various MBS characteristics in our sample. The descriptive statistics reported in columns labeled SOMA are computed across all securities held by the Federal Reserve in the System Open Market Account and these in the columns labeled Market are computed across all securities that are not held by the Federal Reserve. *Fed share* denotes the share of security i that the Federal Reserve holds; *coupon* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *TPO share* is the share of loans originated by a third party; *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing; and *Freddie indicator* is the number of Freddie Mac securities divided by the sum of the number of Freddie Mac and Fannie Mae securities. The variables *loan age*, *credit score*, *loan-to-value*, and *loan size* are weighted averages. † indicates that SOMA securities' sample mean is statistically different ($p < 0.05$) from Market securities. Source: eMBS Inc. and Federal Reserve Bank of New York.

Table 3
Regression Estimates for Prepayment Rates

Panel A: 4.0% - 5.0% Coupons

Variables	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	4.0% Coupon				4.5% Coupon				5.0% Coupon			
Fed ownership	-0.681	-0.427	-0.303	-0.189	3.623***	3.563***	3.761***	3.754***	3.180***	3.475***	3.447***	3.713***
	(0.598)	(0.588)	(0.605)	(0.592)	(0.336)	(0.332)	(0.330)	(0.329)	(0.221)	(0.218)	(0.221)	(0.218)
Loan age	-10.53***	-7.863***	-11.24***	-9.138***	3.865***	4.344***	4.172***	4.615***	3.785***	2.639***	3.713***	2.715***
	(2.477)	(2.472)	(2.400)	(2.414)	(0.336)	(0.324)	(0.339)	(0.330)	(0.177)	(0.190)	(0.175)	(0.187)
(Loan age)^2	0.142***	0.132***	0.151***	0.151***	-0.010***	-0.010***	-0.006***	-0.010***	-0.013***	-0.011***	-0.012***	-0.011***
	(0.014)	(0.018)	(0.014)	(0.018)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Coupon	9.31	18.19***	7.18	15.23**	39.14***	40.23***	45.38***	44.39***	10.76***	5.31***	12.09***	6.20***
	(7.042)	(6.995)	(6.871)	(6.819)	(1.915)	(1.958)	(1.951)	(1.969)	(1.649)	(1.626)	(1.633)	(1.621)
Loan size (×1/1000)	0.068***	0.064***	0.062***	0.061***	0.074***	0.072***	0.072***	0.071***	0.050***	0.050***	0.052***	0.052***
	(0.004)	(0.005)	(0.004)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Coupon × loan age	1.886***	1.368***	1.988***	1.535***	-0.624***	-0.608***	-0.711***	-0.685***	-0.525***	-0.318***	-0.519***	-0.315***
	(0.547)	(0.530)	(0.530)	(0.518)	(0.069)	(0.065)	(0.069)	(0.066)	(0.035)	(0.036)	(0.034)	(0.035)
Factor (×100)	-0.697***	-0.531***	-0.725***	-0.551***	-0.453***	-0.323***	-0.422***	-0.316***	-0.448***	-0.389***	-0.437***	-0.382***
	(0.173)	(0.172)	(0.171)	(0.170)	(0.044)	(0.043)	(0.042)	(0.042)	(0.016)	(0.016)	(0.016)	(0.016)
Freddie	0.327	0.459	0.276	0.292	1.517***	1.384***	1.110***	1.117***	2.052***	2.051***	1.867***	1.936***
	(0.413)	(0.422)	(0.413)	(0.421)	(0.227)	(0.234)	(0.225)	(0.233)	(0.187)	(0.187)	(0.189)	(0.190)
FICO			-0.033	0.014			0.068***	0.065***			0.081***	0.069***
			(0.025)	(0.026)			(0.012)	(0.012)			(0.005)	(0.005)
TPO share			0.033***	0.026***			0.030***	0.018***			0.020***	0.016***
			(0.006)	(0.006)			(0.004)	(0.004)			(0.003)	(0.003)
Refi share			0.042***	0.049***			0.076***	0.044***			-0.015***	-0.031***
			(0.013)	(0.013)			(0.008)	(0.009)			(0.006)	(0.006)
Vintage dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
Geographic dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
# of CUSIPS	2,039	2,039	2,039	2,039	7,820	7,820	7,819	7,819	14,013	14,013	13,991	13,991
Adjusted R-squared	0.504	0.554	0.514	0.561	0.546	0.586	0.561	0.592	0.505	0.534	0.516	0.544

Note: This table presents the OLS estimation results of cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* and other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *loan age*, *loan size*, and *FICO* are weighted-averages. Four regression specifications are estimated separately for each coupon. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 3
continued

Panel B: 5.5% - 6.5% Coupons

Variables	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	5.5% Coupon				6.0% Coupon				6.5% Coupon			
Fed ownership	5.297***	3.629***	5.241***	3.796***	2.250***	2.161***	2.385***	2.249***	2.204***	1.662***	2.306***	1.767***
	(0.186)	(0.180)	(0.181)	(0.179)	(0.238)	(0.237)	(0.237)	(0.235)	(0.455)	(0.450)	(0.450)	(0.444)
Loan age	3.356***	1.156***	3.167***	1.320***	0.563	0.267	1.037***	0.721*	1.314**	1.207**	1.674***	1.599***
	(0.120)	(0.136)	(0.117)	(0.135)	(0.385)	(0.418)	(0.384)	(0.420)	(0.548)	(0.593)	(0.558)	(0.597)
(Loan age)^2	-0.002***	0.004***	-0.002***	0.003***	0.000	0.000	-0.001	-0.001	0.000	-0.001	0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.003)
Coupon	23.72***	4.57***	21.74***	5.78***	-2.76	-3.68*	0.44	-1.66	3.42	4.22	5.99**	6.36**
	(1.184)	(1.224)	(1.152)	(1.228)	(2.127)	(2.147)	(2.158)	(2.191)	(2.817)	(2.871)	(2.912)	(2.962)
Loan size (×1/1000)	0.059***	0.056***	0.060***	0.056***	0.049***	0.046***	0.050***	0.045***	0.067***	0.060***	0.067***	0.059***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Coupon × loan age	-0.565***	-0.280***	-0.515***	-0.293***	-0.132**	-0.116**	-0.198***	-0.161***	-0.233***	-0.235***	-0.284***	-0.279***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.057)	(0.059)	(0.057)	(0.059)	(0.077)	(0.078)	(0.078)	(0.079)
Factor (×100)	-0.328***	-0.245***	-0.324***	-0.253***	-0.421***	-0.382***	-0.421***	-0.379***	-0.289***	-0.251***	-0.300***	-0.252***
	(0.009)	(0.008)	(0.008)	(0.008)	(0.009)	(0.010)	(0.009)	(0.010)	(0.013)	(0.014)	(0.014)	(0.014)
Freddie	3.158***	2.608***	2.252***	2.281***	2.266***	2.482***	2.609***	2.835***	1.605***	1.677***	1.666***	1.705***
	(0.126)	(0.124)	(0.132)	(0.131)	(0.165)	(0.166)	(0.196)	(0.197)	(0.237)	(0.238)	(0.281)	(0.281)
FICO			0.065***	0.035***			0.015***	0.003			0.007	-0.003
			(0.003)	(0.003)			(0.004)	(0.004)			(0.005)	(0.005)
TPO share			0.057***	0.030***			-0.006**	-0.005*			0.001	0.005
			(0.003)	(0.003)			(0.003)	(0.003)			(0.004)	(0.004)
Refi share			-0.013***	-0.038***			-0.052***	-0.065***			-0.043***	-0.068***
			(0.003)	(0.004)			(0.004)	(0.005)			(0.006)	(0.006)
Vintage dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
Geographic dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
# of CUSIPS	34,971	34,971	34,756	34,756	17,764	17,764	17,758	17,758	7,943	7,943	7,942	7,942
Adjusted R-squared	0.319	0.379	0.342	0.388	0.360	0.383	0.367	0.391	0.338	0.362	0.343	0.371

Note: This table presents the OLS estimation results of cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* and other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. Four regression specifications are estimated separately for each coupon. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 4
Regression Estimates for Prepayment Rates

Panel A: 4.0% - 5.0% Coupons

Variables	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	4.0% Coupon				4.5% Coupon				5.0% Coupon			
Fed share	-1.181**	-0.948*	-0.865	-0.721	2.832***	2.522***	2.686***	2.676***	3.332***	3.648***	3.712***	4.007***
	(0.584)	(0.565)	(0.591)	(0.569)	(0.338)	(0.341)	(0.332)	(0.336)	(0.298)	(0.300)	(0.295)	(0.298)
Loan age	-10.25***	-7.529***	-10.99***	-8.834***	3.883***	4.333***	4.167***	4.594***	3.843***	2.734***	3.778***	2.822***
	(2.465)	(2.465)	(2.388)	(2.407)	(0.341)	(0.331)	(0.343)	(0.337)	(0.178)	(0.191)	(0.175)	(0.188)
(Loan age)^2	0.143***	0.130***	0.150***	0.148***	-0.010***	-0.011***	-0.007***	-0.010***	-0.014***	-0.011***	-0.013***	-0.012***
	(0.013)	(0.018)	(0.014)	(0.018)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Coupon	9.850***	18.81***	7.647	15.79**	39.64***	40.46***	45.62***	44.56***	10.68***	5.355***	12.05***	6.280***
	(7.012)	(6.978)	(6.843)	(6.804)	(1.932)	(1.980)	(1.968)	(1.988)	(1.653)	(1.630)	(1.636)	(1.625)
Loan size (×1/1000)	0.069***	0.065***	0.064***	0.062***	0.078***	0.076***	0.077***	0.075***	0.051***	0.050***	0.053***	0.052***
	(0.004)	(0.005)	(0.004)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Coupon × loan age	1.833***	1.313***	1.945***	1.488***	-0.623***	-0.603***	-0.704***	-0.678***	-0.528***	-0.328***	-0.522***	-0.325***
	(0.545)	(0.529)	(0.528)	(0.516)	(0.070)	(0.067)	(0.070)	(0.067)	(0.035)	(0.036)	(0.034)	(0.035)
Factor (×100)	-0.705***	-0.539**	-0.732***	-0.557**	-0.460***	-0.329***	-0.429***	-0.323***	-0.465***	-0.405***	-0.455***	-0.400***
	(0.173)	(0.172)	(0.170)	(0.170)	(0.045)	(0.043)	(0.043)	(0.042)	(0.016)	(0.017)	(0.016)	(0.016)
Freddie	0.338	0.456	0.260	0.275	1.439***	1.280***	1.025***	1.023***	1.678***	1.642***	1.484***	1.533***
	(0.408)	(0.417)	(0.408)	(0.416)	(0.229)	(0.236)	(0.227)	(0.236)	(0.183)	(0.184)	(0.187)	(0.188)
Credit score			-0.030	0.016			0.640***	0.616***			0.081***	0.070***
			(0.025)	(0.026)			(0.012)	(0.012)			(0.005)	(0.005)
TPO share			0.033***	0.026***			0.029***	0.017***			0.020***	0.015***
			(0.006)	(0.006)			(0.004)	(0.004)			(0.003)	(0.003)
Refi share			0.041***	0.048***			0.075***	0.045***			-0.013**	-0.031***
			(0.013)	(0.013)			(0.008)	(0.009)			(0.006)	(0.006)
Vintage dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
Geographic dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
# of CUSIPS	2,040	2,039	2,039	2,039	7,834	7,820	7,819	7,819	14,013	14,013	13,991	13,991
Adjusted R-squared	0.505	0.554	0.515	0.561	0.542	0.582	0.556	0.587	0.502	0.531	0.513	0.540

Note: This table presents the OLS estimation results of cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed share* and other explanatory variables. *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. Four regression specifications are estimated separately for each coupon. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 4
continued

Panel B: 5.5% - 6.5% Coupons

Variables	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	5.5% Coupon				6.0% Coupon				6.5% Coupon			
Fed share	6.683***	4.703***	6.066***	4.567***	4.710***	4.315***	4.814***	4.462***	5.795***	4.596***	5.700***	4.542***
	(0.363)	(0.344)	(0.350)	(0.341)	(0.727)	(0.722)	(0.736)	(0.730)	(1.722)	(1.690)	(1.723)	(1.679)
Loan age	3.470***	1.196***	3.291***	1.347***	0.557	0.268	1.032***	0.725*	1.260**	1.167**	1.616***	1.554***
	(0.121)	(0.136)	(0.118)	(0.136)	(0.383)	(0.421)	(0.383)	(0.424)	(0.548)	(0.594)	(0.558)	(0.599)
(Loan age)^2	-0.002***	0.003***	-0.002***	0.003***	-0.001	-0.000	-0.001	-0.002	0.000	-0.001	0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.003)
Coupon	25.21***	4.669***	23.45***	5.846***	-3.117	-3.978*	0.087	-1.945	3.054	3.903	5.593*	6.034**
	(1.190)	(1.225)	(1.157)	(1.230)	(2.122)	(2.147)	(2.151)	(2.190)	(2.814)	(2.870)	(2.909)	(2.961)
Loan size (×1/1000)	0.060***	0.057***	0.062***	0.057***	0.050***	0.046***	0.051***	0.045***	0.067***	0.060***	0.067***	0.059***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Coupon× loan age	-0.582***	-0.282***	-0.535***	-0.294***	-0.126**	-0.111*	-0.191***	-0.156***	-0.225***	-0.228***	-0.276***	-0.272***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.057)	(0.059)	(0.057)	(0.059)	(0.077)	(0.078)	(0.078)	(0.079)
Factor (×100)	-0.346***	-0.253***	-0.342***	-0.261***	-0.429***	-0.389***	-0.430***	-0.387***	-0.296***	-0.255***	-0.276***	-0.272***
	(0.009)	(0.008)	(0.008)	(0.008)	(0.010)	(0.010)	(0.009)	(0.010)	(0.077)	(0.078)	(0.078)	(0.079)
Freddie	2.676***	2.284***	1.760***	1.980***	1.932***	2.152***	2.258***	2.500***	1.508***	1.607***	1.564***	1.627***
	(0.125)	(0.123)	(0.131)	(0.131)	(0.157)	(0.159)	(0.190)	(0.191)	(0.236)	(0.237)	(0.281)	(0.280)
Credit score			0.067***	0.035***			0.015***	0.003			0.008	-0.003
			(0.003)	(0.003)			(0.004)	(0.004)			(0.005)	(0.005)
TPO share			0.054***	0.025***			-0.006**	-0.005*			0.001	0.005
			(0.003)	(0.003)			(0.003)	(0.003)			(0.004)	(0.004)
Refi share			-0.010***	-0.038***			-0.050***	-0.065***			-0.042***	-0.067***
			(0.003)	(0.004)			(0.004)	(0.005)			(0.006)	(0.006)
Vintage dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
Geographic dummies	—	✓	—	✓	—	✓	—	✓	—	✓	—	✓
# of CUSIPS	34,971	34,971	34,756	34,756	17,764	17,764	17,758	17,758	7,943	7,943	7,942	7,942
Adjusted R-squared	0.310	0.376	0.333	0.383	0.358	0.381	0.366	0.390	0.337	0.361	0.341	0.371

Note: This table presents the OLS estimation results of cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed share* and other explanatory variables. *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. Four regression specifications are estimated separately for each coupon. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 5
Pooled Regression Estimates for Prepayment Rates

Variables	(1)	(2)	(3)	(4)	Variables	(1)	(2)	(3)	(4)
	Independent Variable: *Fed ownership*					Independent Variable: *Fed share*			
Fed ownership	4.505***	3.330***	4.500***	3.441***	Fed share	4.961***	3.905***	4.881***	3.990***
	(0.107)	(0.106)	(0.105)	(0.105)		(0.164)	(0.163)	(0.162)	(0.162)
Loan age	2.510***	3.498***	2.503***	3.581***	Loan age	2.624***	3.497***	2.618***	3.582***
	(0.026)	(0.075)	(0.026)	(0.075)		(0.026)	(0.075)	(0.026)	(0.075)
(Loan age)^2	-0.004***	-0.003***	-0.004***	-0.003***	(Loan age)^2	-0.004***	-0.003***	-0.004***	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
Coupon	10.87***	18.57***	11.70***	19.54***	Coupon	11.01***	18.50***	11.87***	19.51***
	(0.172)	(0.568)	(0.184)	(0.571)		(0.175)	(0.569)	(0.186)	(0.573)
Loan size (×1/1000)	0.058***	0.057***	0.059***	0.057***	Loan size (×1/1000)	0.059***	0.057***	0.060***	0.057***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
Coupon × loan age	-0.395***	-0.554***	-0.385***	-0.552***	Coupon × loan age	-0.413***	-0.554***	-0.403***	-0.553***
	(0.005)	(0.012)	(0.005)	(0.012)		(0.005)	(0.012)	(0.005)	(0.012)
Factor (×100)	-0.359***	-0.292***	-0.356***	-0.296***	Factor (×100)	-0.381***	-0.305***	-0.378***	-0.310***
	(0.005)	(0.005)	(0.005)	(0.005)		(0.005)	(0.005)	(0.005)	(0.005)
Freddie	2.484***	2.301***	1.854***	2.038***	Freddie	1.987***	1.958***	1.367***	1.713***
	(0.078)	(0.077)	(0.083)	(0.082)		(0.077)	(0.075)	(0.082)	(0.082)
FICO			0.059***	0.036***	FICO			0.060***	0.036***
			(0.002)	(0.002)				(0.002)	(0.002)
TPO share			0.030***	0.017***	TPO share			0.028***	0.015***
			(0.001)	(0.001)				(0.001)	(0.001)
Refi share			-0.009***	-0.035***	Refi share			-0.007***	-0.035***
			(0.002)	(0.002)				(0.002)	(0.002)
Vintage dummies	—	✓	—	✓		—	✓	—	✓
Geographic dummies	—	✓	—	✓		—	✓	—	✓
Coupon-vintage dummies	—	✓	—	✓		—	✓	—	✓
# of CUSIPS	84,565	84,565	84,305	84,305		84,565	84,565	84,305	84,305
Adjusted R-squared	0.404	0.456	0.416	0.462		0.398	0.453	0.410	0.459

Note: This table presents the OLS estimation results of pooled cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* (in the first set of columns (1)-(4)) or *Fed share* (in the second set of columns (1)-(4)) as well as other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 6
Propensity Score Matching Results

	4.0% Coupon	4.5% Coupon	5.0% Coupon
ATT (%)	0.47	0.16	3.43***
	(1.17)	(0.66)	(0.43)
Min. Rosenbaum Bound	1.00	1.00	1.50
Pseudo R-squared for Entire Sample	0.247	0.367	0.341
Pseudo R-squared for Matched Sample	0.027	0.033	0.008

	5.5% Coupon	6.0% Coupon	6.5% Coupon
ATT (%)	4.59***	2.86***	3.01***
	(0.35)	(0.35)	(0.59)
Min. Rosenbaum Bound	2.00	1.50	1.40
Pseudo R-squared for Entire Sample	0.396	0.319	0.131
Pseudo R-squared for Matched Sample	0.011	0.003	0.004

Note: This table presents the average treatment effect for the treated (ATT) securities held by the Federal Reserve. Values for the ATT reported using a local linear regression matching estimator. Abadie and Imbens (2006) heteroskedasticity-consistent analytical standard errors are reported in parentheses. The minimum Rosenbaum bound reports the minimum level of hidden bias that produces a confidence interval that includes zero (see Rosenbaum (2002)). Pseudo R-squared values of the matching regressions are reported to demonstrate that an appropriately balanced sample was achieved. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 7

Pooled Regression Estimates for Prepayment Rates (Share of Third Party Origination > 0.50)

Variables	(1)	(2)	(3)	(4)	Variables	(1)	(2)	(3)	(4)
	Independent Variable: *Fed ownership*					Independent Variable: *Fed share*			
Fed ownership	5.006***	4.036***	5.174***	4.213***	Fed share	5.927***	5.240***	6.266***	5.531***
	(0.171)	(0.169)	(0.170)	(0.169)		(0.237)	(0.240)	(0.239)	(0.242)
Loan age	3.334***	4.629***	3.256***	4.672***	Loan age	3.507***	4.605***	3.441***	4.647***
	(0.052)	(0.154)	(0.521)	(0.153)		(0.053)	(0.154)	(0.053)	(0.154)
(Loan age)^2	-0.003***	-0.003***	-0.003***	-0.005***	(Loan age)^2	-0.003***	-0.003***	-0.003***	-0.005***
	(0.000)	(0.001)	(0.000)	(0.001)		(0.000)	(0.001)	(0.000)	(0.001)
Coupon	10.34***	20.15***	10.66***	20.40***	Coupon	10.59***	19.79***	10.94***	19.99***
	(0.298)	(0.945)	(0.328)	(0.942)		(0.303)	(0.945)	(0.331)	(0.942)
Loan size (×1/1000)	0.041***	0.038***	0.046***	0.041***	Loan size (×1/1000)	0.040***	0.037***	0.045***	0.040***
	(0.001)	(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)	(0.001)
Coupon × loan age	-0.531***	-0.750**	-0.506***	-0.711***	Coupon × loan age	-0.561***	-0.747***	-0.538***	-0.708***
	(0.010)	(0.027)	(0.010)	(0.026)		(0.010)	(0.027)	(0.010)	(0.003)
Factor (×100)	-0.409***	-0.375***	-0.394***	-0.367***	Factor (×100)	-0.441***	-0.398***	-0.427***	-0.391***
	(0.008)	(0.008)	(0.008)	(0.008)		(0.008)	(0.008)	(0.008)	(0.008)
Freddie	0.279*	1.006***	0.296**	1.183***	Freddie	-0.303**	0.644***	-0.276*	0.815***
	(0.148)	(0.148)	(0.147)	(0.147)		(0.144)	(0.145)	(0.143)	(0.144)
FICO			0.043***	0.028***	FICO			0.041***	0.028***
			(0.004)	(0.004)				(0.004)	(0.004)
TPO share			-0.060***	-0.040***	TPO share			-0.063***	-0.042***
			(0.004)	(0.004)				(0.004)	(0.004)
Refi share			-0.049***	-0.084***	Refi share			-0.050***	-0.085***
			(0.004)	(0.005)				(0.004)	(0.005)
Vintage dummies	—	✓	—	✓		—	✓	—	✓
Geographic dummies	—	✓	—	✓		—	✓	—	✓
Coupon-vintage dummies	—	✓	—	✓		—	✓	—	✓
# of CUSIPS	27,815	27,815	27,770	27,770		27,815	27,815	27,770	27,770
Adjusted R-squared	0.450	0.497	0.461	0.509		0.445	0.496	0.457	0.508

Note: This table presents the OLS estimation results of pooled cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* (in the first set of columns (1)-(4)) or *Fed share* (in the second set of columns (1)-(4)) as well as other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 8
Pooled Regression Estimates for Prepayment Rates (Production Years before 2009)

Variables	(1)	(2)	(3)	(4)	Variables	(1)	(2)	(3)	(4)
	Independent Variable: *Fed ownership*					Independent Variable: *Fed share*			
Fed ownership	3.353***	2.855***	3.437***	2.885***	Fed share	4.092***	3.664***	4.083***	3.555***
	(0.123)	(0.123)	(0.122)	(0.123)		(0.272)	(0.274)	(0.271)	(0.274)
Loan age	0.030	0.283***	0.136**	0.557***	Loan age	0.024	0.291***	0.129**	0.560***
	(0.052)	(0.101)	(0.053)	(0.103)		(0.053)	(0.102)	(0.055)	(0.104)
(Loan age)^2	0.001***	0.006***	0.001***	0.005***	(Loan age)^2	0.001***	0.005***	0.001***	0.005***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
Coupon	-3.397***	-0.487	-2.408***	1.277*	Coupon	-3.888***	-0.581	-2.905***	1.185*
	(0.339)	(0.697)	(0.354)	(0.717)		(0.343)	(0.699)	(0.359)	(0.719)
Loan size (×1/1000)	0.056***	0.051***	0.056***	0.050***	Loan size (×1/1000)	0.057***	0.051***	0.057***	0.050***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.001)	(0.001)	(0.001)	(0.001)
Coupon × loan age	-0.074***	-0.187***	-0.083	-0.211***	Coupon × loan age	-0.074***	-0.187***	-0.082***	-0.212***
	(0.008)	(0.014)	(0.008)	(0.014)		(0.008)	(0.014)	(0.008)	(0.014)
Factor (×100)	-0.316***	-0.284***	-0.322***	-0.289***	Factor (×100)	-0.329***	-0.294***	-0.336***	-0.299***
	(0.005)	(0.005)	(0.005)	(0.005)		((0.005)	(0.005)	(0.005)	(0.005)
Freddie	2.602***	2.404***	2.271***	2.216***	Freddie	2.185***	2.069***	1.851***	1.899***
	(0.087)	(0.087)	(0.096)	(0.096)		(0.085)	(0.085)	(0.095)	(0.095)
FICO			0.035***	0.020***	FICO			0.035***	0.020***
			(0.002)	(0.002)				(0.002)	(0.002)
TPO share			0.015***	0.012***	TPO share			0.014***	0.010***
			(0.002)	(0.002)				(0.002)	(0.002)
Refi share			-0.025***	-0.045***	Refi share			-0.023***	-0.045***
			(0.002)	(0.002)				(0.002)	(0.002)
Vintage dummies	—	✓	—	✓		—	✓	—	✓
Geographic dummies	—	✓	—	✓		—	✓	—	✓
Coupon-vintage dummies	—	✓	—	✓		—	✓	—	✓
# of CUSIPS	69,417	69,417	69,191	69,191		69,417	69,417	69,191	69,191
Adjusted R-squared	0.317	0.347	0.320	0.353		0.309	0.344	0.315	0.350

Note: This table presents the OLS estimation results of pooled cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* (in the first set of columns (1)-(4)) or *Fed share* (in the second set of columns (1)-(4)) as well as other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 9
Pooled Regression Estimates for Prepayment Rates (Production Years 2009 and 2010)

Variables	(1)	(2)	(3)	(4)	Variables	(1)	(2)	(3)	(4)
	Independent Variable: *Fed ownership*					Independent Variable: *Fed share*			
Fed ownership	3.337***	2.661***	3.529***	2.842***	Fed share	3.039***	2.161***	3.105***	2.288***
	(0.220)	(0.215)	(0.218)	(0.215)		(0.224)	(0.217)	(0.223)	(0.217)
Loan age	-1.797***	1.514***	-1.356***	1.549***	Loan age	-1.950***	1.346***	-1.529***	1.368***
	(0.270)	(0.334)	(0.289)	(0.342)		(0.274)	(0.338)	(0.293)	(0.348)
(Loan age)^2	0.102***	0.101***	0.100***	0.101***	(Loan age)^2	0.102***	0.101***	0.100***	0.101***
	(0.004)	(0.005)	(0.004)	(0.005)		(0.004)	(0.005)	(0.004)	(0.005)
Coupon	3.67***	22.80***	8.55***	25.08***	Coupon	3.23***	22.49***	7.94***	24.71***
	(0.498)	(1.228)	(0.592)	(1.235)		(0.499)	(1.236)	(0.594)	(1.245)
Loan size (×1/1000)	0.073***	0.080***	0.074***	0.081***	Loan size (×1/1000)	0.075***	0.082***	0.077***	0.083***
	(0.001)	(0.002)	(0.001)	(0.002)		(0.001)	(0.002)	(0.001)	(0.002)
Coupon × loan age	0.151***	-0.507***	0.062	-0.519***	Coupon × loan age	0.180***	-0.476***	0.095*	-0.486***
	(0.052)	(0.063)	(0.055)	(0.064)		(0.052)	(0.064)	(0.056)	(0.065)
Factor (×100)	-0.461***	-0.481***	-0.464***	-0.477***	Factor (×100)	-0.478***	-0.492***	-0.482***	-0.490***
	(0.027)	(0.024)	(0.027)	(0.024)		(0.027)	(0.024)	(0.027)	(0.024)
Freddie	1.264***	1.078***	1.036***	0.937***	Freddie	1.200**	1.003***	0.969***	0.864***
	(0.160)	(0.157)	(0.159)	(0.156)		(0.160)	(0.157)	(0.159)	(0.156)
FICO			0.103***	0.074***	FICO			0.100***	0.072***
			(0.006)	(0.006)				(0.006)	(0.006)
TPO share			0.012***	0.009***	TPO share			0.011***	0.008***
			(0.003)	(0.003)				(0.003)	(0.003)
Refi share			0.032***	0.022***	Refi share			0.031***	0.022***
			(0.006)	(0.006)				(0.006)	(0.006)
Vintage dummies	—	✓	—	✓		—	✓	—	✓
Geographic dummies	—	✓	—	✓		—	✓	—	✓
Coupon-vintage dummies	—	✓	—	✓		—	✓	—	✓
# of CUSIPS	15,148	15,148	15,114	15,114		15,148	15,148	15,114	15,114
Adjusted R-squared	0.507	0.587	0.519	0.593		0.506	0.586	0.517	0.591

Note: This table presents the OLS estimation results of pooled cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* (in the first set of columns (1)-(4)) or *Fed share* (in the second set of columns (1)-(4)) as well as other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 10
Pooled Regression Estimates for Prepayment Rates (Excluding Delinquency Repurchases)

Variables	(1)	(2)	(3)	(4)	Variables	(1)	(2)	(3)	(4)
	Independent Variable: *Fed ownership*					Independent Variable: *Fed share*			
Fed ownership	4.644***	4.490***	4.709***	4.458***	Fed share	4.155***	5.859***	4.443***	5.925***
	(0.201)	(0.194)	(0.197)	(0.191)		(0.307)	(0.300)	(0.302)	(0.295)
Loan age	2.481***	2.939***	2.500***	3.072***	Loan age	2.508***	2.894***	2.541***	3.029***
	(0.043)	(0.116)	(0.043)	(0.114)		(0.044)	(0.118)	(0.044)	(0.115)
(Loan age)^2	-0.003***	-0.002***	-0.003***	-0.003***	(Loan age)^2	-0.003***	-0.002***	-0.003***	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
Coupon	6.26***	11.90***	8.76***	14.02***	Coupon	5.96***	11.72***	8.56***	13.83***
	(0.281)	(0.830)	(0.298)	(0.829)		(0.284)	(0.836)	(0.300)	(0.835)
Loan size (×1/1000)	0.038***	0.038***	0.042***	0.040***	Loan size (×1/1000)	0.038***	0.036***	0.042***	0.038***
	(0.001)	(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)	(0.001)
Coupon × loan age	-0.404***	-0.478**	-0.403***	-0.474***	Coupon × loan age	-0.410***	-0.477***	-0.412***	-0.472***
	(0.008)	(0.018)	(0.008)	(0.018)		(0.008)	(0.018)	(0.008)	(0.018)
Factor (×100)	-0.434***	-0.362***	-0.429***	-0.366***	Factor (×100)	-0.446***	-0.376***	-0.442***	-0.379***
	(0.008)	(0.008)	(0.008)	(0.008)		(0.008)	(0.008)	(0.008)	(0.008)
FICO			0.102***	0.740***	FICO			0.103***	0.074***
			(0.003)	(0.003)				(0.003)	(0.003)
TPO share			-0.001	-0.014***	TPO share			0.000	-0.014***
			(0.002)	(0.002)				(0.002)	(0.002)
Refi share			-0.029***	-0.051***	Refi share			-0.029***	-0.053***
			(0.004)	(0.004)				(0.004)	(0.004)
Vintage dummies	—	✓	—	✓		—	✓	—	✓
Geographic dummies	—	✓	—	✓		—	✓	—	✓
Coupon-vintage dummies	—	✓	—	✓		—	✓	—	✓
# of CUSIPS	35,766	35,766	35,749	35,749		35,766	35,766	35,749	35,749
Adjusted R-squared	0.314	0.387	0.339	0.404		0.308	0.385	0.334	0.402

Note: This table presents the OLS estimation results of pooled cross-sectional regressions of total prepayment rates—computed as the amount of prepayments excluding delinquency repurchases from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* (in the first set of columns (1)-(4)) or *Fed share* (in the second set of columns (1)-(4)) as well as other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. All specifications include a constant (not reported). Due to data limitations, only Freddie Mac-guaranteed securities are included in this table. Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 11
Pooled Regression Estimates for Prepayment Rates: Large Servicers

Variables	(1)	(2)	(3)	(4)	Variables	(1)	(2)	(3)	(4)
	Independent Variable: *Fed ownership*					Independent Variable: *Fed share*			
Fed ownership	3.637***	2.123***	3.709***	2.364***	Fed share	4.167***	2.685***	4.129***	2.867***
	(0.131)	(0.132)	(0.129)	(0.130)		(0.181)	(0.188)	(0.178)	(0.186)
Loan age	2.353***	3.161***	2.347***	3.233***	Loan age	2.467***	3.159***	2.460***	3.234***
	(0.024)	(0.067)	(0.024)	(0.067)		(0.024)	(0.067)	(0.024)	(0.067)
(Loan age)^2	-0.004***	-0.003***	-0.004***	-0.003***	(Loan age)^2	-0.004***	-0.003***	-0.004***	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
Coupon	10.13***	18.45***	10.85***	19.11***	Coupon	10.26***	18.37***	11.00***	19.08***
	(0.160)	(0.501)	(0.169)	(0.504)		(0.162)	(0.502)	(0.171)	(0.505)
Loan size (×1/1000)	0.056***	0.054***	0.056***	0.054***	Loan size (×1/1000)	0.057***	0.053***	0.057***	0.054***
	(0.000)	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
Coupon × loan age	-0.368***	-0.504***	-0.358***	-0.500***	Coupon × loan age	-0.386***	-0.504***	-0.376***	-0.501***
	(0.004)	(0.011)	(0.004)	(0.011)		(0.004)	(0.011)	(0.004)	(0.011)
Factor (×100)	-0.356***	-0.280***	-0.353***	-0.286***	Factor (×100)	-0.377***	-0.292***	-0.374***	-0.298***
	(0.005)	(0.005)	(0.005)	(0.005)		(0.005)	(0.005)	(0.005)	(0.005)
Freddie	1.566***	1.123***	0.953***	0.920***	Freddie	1.090***	0.853***	0.486***	0.664***
	(0.073)	(0.071)	(0.078)	(0.076)		(0.072)	(0.069)	(0.077)	(0.075)
FICO			0.055***	0.033***	FICO			0.056***	0.033***
			(0.002)	(0.002)				(0.002)	(0.002)
TPO share			0.030***	0.015***	TPO share			0.029***	0.013***
			(0.001)	(0.001)				(0.001)	(0.001)
Refi share			-0.009***	-0.040***	Refi share			-0.007***	-0.040***
			(0.002)	(0.002)				(0.002)	(0.002)
Bank of America	-4.487***	-5.332***	-4.493***	-5.859***	Bank of America	-4.319***	-5.368***	-4.340***	-5.909***
	(0.094)	(0.288)	(0.093)	(0.288)		(0.089)	(0.290)	(0.088)	(0.290)
Citigroup	-0.833***	-1.973***	-0.976***	-2.171***	Citigroup	-0.599***	-1.893***	-0.754***	-2.108***
	(0.133)	(0.317)	(0.132)	(0.320)		(0.125)	(0.317)	(0.124)	(0.321)
J.P. Morgan	11.17***	9.209***	11.18***	9.167***	J.P. Morgan	11.38***	9.235***	11.35***	9.180***
	(0.133)	(0.335)	(0.131)	(0.336)		(0.124)	(0.334)	(0.123)	(0.336)
Wells Fargo	3.779***	4.558***	3.596***	4.391***	Wells Fargo	4.009***	4.645***	3.808***	4.459***
	(0.122)	(0.372)	(0.123)	(0.377)		(0.116)	(0.373)	(0.117)	(0.377)
Bank of America × Fed ownership	0.767***	0.577***	0.778***	0.361*	Bank of America × Fed share	0.563**	0.078	0.710**	-0.072
	(0.187)	(0.195)	(0.184)	(0.193)		(0.282)	(0.320)	(0.276)	(0.319)
Citigroup × Fed ownership	1.637***	1.070***	1.175***	0.843***	Citigroup × Fed share	1.811***	0.876*	1.062***	0.679
	(0.256)	(0.271)	(0.252)	(0.270)		(0.379)	(0.450)	(0.375)	(0.447)
J.P. Morgan × Fed ownership	0.529**	1.056***	0.288	0.788***	J.P. Morgan × Fed share	-0.243	2.697***	-0.401	2.539***
	(0.269)	(0.263)	(0.265)	(0.263)		(0.441)	(0.470)	(0.435)	(0.470)
Wells Fargo × Fed ownership	2.232***	2.061***	2.185***	1.775***	Wells Fargo × Fed share	3.685***	3.197***	3.862***	2.804***
	(0.291)	(0.277)	(0.291)	(0.276)		(0.574)	(0.554)	(0.573)	(0.557)
Vintage dummies	—	✓	—	✓		—	✓	—	✓
Geographic dummies	—	✓	—	✓		—	✓	—	✓
Coupon-vintage dummies	—	✓	—	✓		—	✓	—	✓
Large servicer-vintage interactions	—	✓	—	✓		—	✓	—	✓
# of CUSIPS	84,565	84,565	84,305	84,305		84,565	84,565	84,305	84,305
Adjusted R-squared	0.523	0.581	0.534	0.588		0.518	0.580	0.529	0.586

Note: This table presents the OLS estimation results of pooled cross-sectional regressions of total prepayment rates—computed as the amount of prepayments from 06/2010-06/2012 divided by the remaining principal balance as of 06/2010—on *Fed ownership* (in the first set of columns (1)-(4)) or *Fed share* (in the second set of columns (1)-(4)) as well as other explanatory variables. *Fed ownership* is a dummy variable that equals one if security i is held by the Federal Reserve; *Fed share* denotes the share of security i that the Federal Reserve holds; *wac* is the weighted-average coupon on the underlying mortgage pool; *factor* is the fraction of the original principal balance that remains to be repaid; *Freddie* is a dummy variable that equals one if security i is a Freddie Mac security; *FICO* is the FICO credit score; *TPO share* is the share of loans originated by a third party; and *refi share* is the share of loans in a pool that were originated as a result of a previous refinancing. The variables *wala*, *wals*, and *woacs* are weighted-averages. All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 12
Loan-Level Rates of Refinancing

Panel A: Conventional loans

	Share of loans refinancing (since June 2010)			
	Mortgages held in whole-loan portfolios	Matched securitized mortgages	Difference	Memo: Difference as a % of securitized refi rate
Jun 11	10.2%	15.1%	4.9%***	32.5%
Dec 11	13.7%	21.3%	7.6%***	35.7%
Jun 12	18.3%	28.6%	10.3%***	36.0%
Dec 12	23.9%	37.9%	14.0%***	36.9%
Jun 13	29.3%	46.7%	17.4%***	37.3%
Dec 13	32.7%	51.5%	18.8%***	36.5%

Panel B: FHA and VA loans

	Share of loans refinancing (since June 2010)			
	Mortgages held in whole-loan portfolios	Matched securitized mortgages	Difference	Memo: Difference as a % of securitized refi rate
Jun 11	4.5%	11.8%	7.3%***	61.9%
Dec 11	5.7%	16.7%	11.0%***	65.9%
Jun 12	6.3%	22.6%	16.3%***	72.1%
Dec 12	12.2%	29.5%	17.3%***	58.6%
Jun 13	13.0%	36.1%	23.1%***	64.0%
Dec 13	13.4%	38.5%	25.1%***	65.2%

This table presents the share of individual mortgages that have refinanced between June 2010 and the dates listed to the left. The first column limits the sample to mortgages held outright in whole-loan portfolios, while the second column limits the sample to propensity-score-matched mortgages that have been securitized. The third column computes the difference, which is the propensity score matching estimate of the effect of securitization on the rate of refinancing. The fourth column expresses the difference as a percent of the securitized mortgage refinancing rate. Panel A reports results for conventional mortgages, while Panel B reports results for FHA and VA loans. Matched securtized mortgages in Panel B therefore back Ginnie Mae pools only. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.

Table 13
Regression Estimates for Banks' MBS Holdings

Variables	(1)	(2)	(3)	(1)	(2)	(3)
	Sample period: 01/1997-06/2014			Sample period: 01/2009-06/2014		
ΔMBS$_{t-1}$	0.082	0.067	0.073	-0.083	-0.097	-0.172
	(0.066)	(0.066)	(0.065)	(0.099)	(0.117)	(0.115)
ΔFed MBS$_t$	-0.089**	-0.164***	-0.178***	-0.223***	-0.290***	-0.310***
	(0.043)	(0.049)	(0.050)	(0.077)	(0.073)	(0.084)
ΔMBS outstanding$_{t-1}$	0.059	0.121	0.126	0.238**	0.243***	0.259**
	(0.072)	(0.083)	(0.087)	(0.101)	(0.084)	(0.115)
ΔAssets$_{t-1}$		-0.011	-0.010		0.004	0.012
		(0.015)	(0.015)		(0.030)	(0.032)
ΔCapital$_{t-1}$		0.156	0.209		0.054	0.066
		(0.135)	(0.138)		(0.165)	(0.195)
ΔReal estate loans$_{t-1}$		-0.039	-0.063		0.053	0.040
		(0.050)	(0.051)		(0.090)	(0.103)
Financial stress index$_{t-1}$		2.228*	2.433*		5.056***	5.615***
		(1.307)	(1.318)		(1.737)	(1.843)
IP growth$_{t-1}$		3.087	4.027**		8.089**	8.246**
		(1.922)	(1.959)		(3.109)	(3.203)
ΔTreasury notes and bonds outstanding$_t$		0.051***	0.053**		0.019	0.020
		(0.020)	(0.021)		(0.024)	(0.025)
Month dummies	—	—	✓	—	—	✓
# of observations	210	210	210	66	66	66
Adjusted R-squared	0.010	0.034	0.071	0.158	0.223	0.171

Note: This table presents the OLS estimation results of changes in banks' MBS holdings on the lagged dependent variable, the change in Federal Reserve MBS holdings, and the lagged change of the stock of outstanding 30-year Fannie Mae and Freddie Mac MBS. Some specifications also include the lagged differences of system-wide assets, capital, and real estate loans, as well as a lagged index of financial stress, lagged industrial production growth, the difference in Treasury notes and bonds outstanding (ex-SOMA), and month dummies. The estimation sample is 01/1997-06/2014 for the first set of columns (1)-(3) and 01/2009-06/2014 for the second set of columns (1)-(3). All specifications include a constant (not reported). Robust standard errors are reported in parentheses. Statistical significance: *** $p < 0.01$,** $p < 0.05$,* $p < 0.10$.