Information Asymmetries in the Mortgage Backed Securities Market

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Abstract

One of the primary results of studying asymmetric information as part of information economics over the last 30 years has been a theory of markets for lemons—that is, markets for goods that are likely to be of poor quality. Unfortunately, it has proven difficult to directly test the lemons theory because the causative factor—asymmetric information—implies that key quality variables are not observable. In this paper, we avoid this problem by studying the market for mortgage backed securities (MBS), a market which exhibits significant asymmetric information on an *ex ante* basis, but *ex post* reveals individual security qualities. In this market, some of the MBS produced in any given month are repackaged into multi-class security structures where certain classes enjoy higher priority claims on the underlying mortgage cash flows than others. As shown in DeMarzo and Duffie (1998), these security structures are optimal when the market values of the underlying assets are sensitive to private information held by the issuer of the securities. Utilizing a comprehensive dataset of all Freddie Mac Gold Participation Certificates (PCs) issued between 1991 and 2002, we show that, consistent with lemons theory, the PCs used to construct multi-class MBS tend to be of lower quality than other PCs. Our results suggest that structured multi-class securities, which after years of explosive growth now surpass traditional single-class securities in importance, are a market response to the problem of efficiently allocating capital when problems of asymmetric information are acute. Our results also have implications for public policies related to government sponsored enterprises.

1 Introduction

One benefit of studying asymmetric information as part of information economics over the last 35 years has been a theory of markets for lemons—that is, for goods likely to be of poor quality. The seminal paper by Akerloff (1970) shows how in markets with asymmetric information, only goods of the lowest quality ("lemons") are traded. Unfortunately, it has proven difficult to test the theory of markets for lemons because the causative factor—asymmetric information—necessarily makes it difficult to observe the key quality variables that determine goods prices.[1]

In this paper, we use the market for mortgage-backed securities (MBS) to test the theory of lemons markets. Mortgage-backed securities are bonds secured by pools of residential home mortgages, with the mortgage payments passed through to the holders of the MBS. One of the largest bond markets in the U.S., the MBS market is interesting in its own right.[2] In the context of testing lemons theory, however, the MBS market is of interest for two reasons. First, the market exhibits significant information asymmetries among various of its participants. Mortgage-backed securities primarily trade in broker markets with little systematic public disclosure of either transaction prices or trade volumes.[3] Moreover, the market is dominated by two government sponsored enterprises (GSEs), Fannie Mae and Freddie Mac. These GSEs have chosen not to release all of the information available to them regarding the mortgages backing MBS.[4] The market thus contains an important degree of asymmetric information *ex ante* concerning the prices and likely payment behavior of the mortgages in different MBS pools. However, the payment behavior of each mortgage pool is revealed *ex post* in terms of the rate of terminations (sum of prepayments and defaults). Termination rates are critical determinants of the *ex post* returns on MBS because discounted MBS (those with coupons below the current par coupon) will earn excess returns relative to other MBS if their termination rates turn out to be faster than the rates embedded in the initial market prices, and vice versa for premium MBS.

[1] The only other direct test of the lemons model that we are aware of is Bond (1982).

[2] In 2004, originations of home mortgages in the United States totaled \$2.8 trillion, of which \$1.8 trillion, or 65%, were repackaged as MBS (*Inside MBS & ABS*, February 18, 2005).

[3] This stands in contrast to many other securities markets; most recently, the other major bond markets have increased the transparency of their operations. In the municipal bond market, the Municipal Securities Rulemaking Board has implemented a trade reporting and dissemination system and plans to gradually move that market to real-time reporting of transaction prices and volumes. In the corporate bond market, including the high-yield submarket, the National Association of Securities Dealers has implemented a system much like that in the muni market.

[4] The issue of asymmetric information in the MBS market is studied in United States Department of the Treasury (2003), a staff report of the Task Force on Mortgage-Backed Securities Disclosure. Following the release of this report, both GSEs "voluntarily" expanded the range of information they release on newly issued MBS, although potentially important information is still not released.

The second reason that the MBS market is of interest is that a substantial share of MBS are repackaged into multi-class securities by the GSEs and investment banks. In a multi-class securitization, some fraction of the total face value of the securities is allocated to senior bond classes with first priority claims on the cash flows of the underlying assets, while the more junior classes are impacted by low quality collateral. The prices of the securities remain efficient, since asymmetric information has little relevance to the senior classes, while the junior classes are traded among informed agents.[5] As shown by DeMarzo (2003) and DeMarzo and Duffie (1998), these capital structures are optimal when the values of the underlying assets are sensitive to private information held by the security issuer.[6] Hence multi-class MBS can be viewed as a market response to the lemons problem that might otherwise render inoperative the market for single-class MBS.

We base our empirical work on a comprehensive dataset of all Freddie Mac Gold Participation Certificates (PCs) issued between 1991 and 2002. We compare the performance of PCs used to create single-class securities versus those used to create structured multi-class securities. Our key result is that, in rising interest-rate environments, pools selected as collateral for multi-class securitizations tend to return principal at a significantly slower rate than pools that are not so selected, even after controlling for all of the publicly-available information about these pools. Similarly, in falling interest-rate environments, pools that are selected as collateral for multi-class securitizations return principal at a faster rate than the pools that are not so selected. Hence in the absence of a price discount to reflect the differential payment speeds, MBS pools used as collateral for multi-class securitizations would earn lower returns than the those pools not used in the multi-class market; in other words, the multi-class MBS market is a market for lemons. Employing a model of MBS prices, we estimate that the pools backing multi-class MBS are discounted, on average, by approximately six cents per hundred dollars of principal, with discounts as high as 20 cents per hundred dollars in certain instances.[7]

Understanding the effects of information asymmetries in the MBS market is also relevant

[5]On the other hand, the prices would be inefficient if uninformed agents tend to overbid or underbid for pools, reflecting the limited information available to them. Unfortunately, we are unable to test for pricing efficiency because we know of no continuing source of prices for individual MBS pools. However, our tests to determine which MBS pools are lemons are unaffected by whether the actual market prices are efficient or not.

[6]A number of other security design papers have focused on the role of asset bundling in markets with information asymmetries (see, for example, Diamond and Verrecchia (1991); Boot and Thakor (1997); Glaeser and Kallal (1997)). These papers focus on the information asymmetries between security issuers, investment-bank intermediaries, and final investors. None of these papers contain empirical tests; to our knowledge this paper is the first to use data on multi-class securities to test the lemons theory.

[7]Recalling that the total size of the market for structured MBS is several hundred billion dollars, the aggregate discount is substantial.

to public policymakers and market participants. Informational asymmetries in this market are important to policymakers because regulatory oversight dictates many aspects of the MBS market structure and likely contributes to the dominance of the GSEs in both MBS trading and portfolio investment. Furthermore, the functioning of the market is of concern to policymakers who focus on the interests of U.S. homeowners, since about two-thirds of residential mortgage loans originated in the U.S. are securitized. MBS are also very widely held investment instruments, hence issues related to the performance of MBS are likely to have implications for the broader U.S. financial markets, as well.

This paper is organized as follows. In the next section, we discuss the institutional details and information asymmetries in the market for Freddie Mac PCs. Section 3 lays out our strategy for identifying PCs that are lemons and presents our empirical results. Section 4 concludes.

2 Information Asymmetries and Freddie Mac PCs

2.1 Market Overview

Most Freddie Mac PCs have been issued through the 30 Year Gold Program. As shown in Table 1, total monthly pool issuance from 1991 through 2002 was 85,988 pools which in aggregate accounted for 12.5 million mortgages and $1.5 trillion of mortgage principal. The recent refinancing boom of 2001 and 2002 coincided with the introduction of 15 year Freddie Mac PCs, however, for the most part PCs are collateralized with 30-year mortgages. The Balloon PCs are collateralized by mortgages that amortize over 30 years but are due in full in five or seven years; Mini PCs are smaller seasoned pools. As can be seen from Table 1, these latter two types of collateral back only small shares of total PC issuance.

Freddie Mac issues most of its PCs through swap programs in which mortgage originators accumulate conforming mortgages into pools that are then swapped for Freddie Mac PCs. The PCs obtained by the originators via swaps are collateralized by the same mortgages that the originator transfers to Freddie Mac. The pool sizes are surprisingly small, averaging just 172 mortgages in 2002. In Table 2, we provide some summary statistics for the 61,929 unseasoned PC pools in our sample. Unseasoned pools are those with a weighted-average remaining term of 359 or more months at the time of origination. We focus on these pools in our empirical analysis because forecasting the seasoning patterns of mortage pools is a key element in selecting lemons.[8] For these pools, the weighted average coupons vary by year

[8]Seasoning refers to the conventional wisdom that, for a given interest-rate decline, mortgage pools closer to their origination dates tend to exhibit slower prepayments. In contrast, "burnout" refers to the conventional wisdom that a given decline in interest rates elicits less and less prepayment response from a

reflecting the term structure of interest rates at the time of origination; in general, long-term interest rates are falling over our sample period, as reflected in the declining weighted-average coupon rates. In our empirical tests, we focus on unseasoned pools with a weighted average remaining term of 359 months at the origination of the pool. The average balance in these pools ranges from about $2.6 million to $27.6 million and the trend appears to be toward larger pool balances in the later years of the sample.

Freddie Mac and Fannie Mae both repurchase large shares of their own guaranteed pools, as well as pools of the other GSE. As shown in Figure 1, beginning in 1993, Freddie Mac has steadily increased its holdings of its own PCs. By year-end 2002, Freddie Mac's portfolio holdings of it own PCs accounted for $393 billion out of the total outstanding stock of $1.162 trillion. Freddie Mac repurchases its PCs through trades with investment banks in a brokered market.[9]

2.2 PC Market Microstructure

Freddie Mac PCs are traded on both a to-be-announced and a pool-specific basis. Unfortunately, there is no publicly available information documenting aggregate trade volumes on these markets. Moreover, there is little information concerning the trade volumes in individual securities, but the information that does exist suggests that individual pools do not trade frequently.[10]

In the to-be-announced (TBA) market, pools are traded for forward delivery on a specified settlement day. Prices quoted in the TBA market are for contracts that specify only the type of PC (*e.g.*, 30-year fixed rate Freddie Mac Gold PC), the weighted average coupon, and the date of delivery. Pools to be assembled for future delivery do not have determinate pool-specific characteristics at the time of forward contracting, so it is not feasible to embed such pool-specific characteristics into the prices of the forward contracts.

As suggested by Glaeser and Kallal (1997), one possible interpretation of the TBA market is that the TBA prices coalesce around the worth of the least valuable, but deliverable, mortgage pools.[11] The market gains liquidity from TBA trading if there is less uncertainty about the value which the market should assign to the worst security than about the values which the market should assign to more valuable securities. As shown by Gorton and Pen-

pool as it ages.

[9]These purchases are primarily financed by the issuance of Agency bonds.

[10]According to the Bond Market Association, in 2004 the daily trading volume for third party trades of MBS equaled about 4% of the outstanding value, compared to a 6% ratio for U.S. Treasuries.

[11]Mortgage originators are also active traders of the PCs obtained through the swap market; these PCs are collateralized by their own mortgages. From the viewpoint of the originator the decision to sell a pool TBA must reflect a trade-off between the opportunity cost of not selling versus the cost of selling at a price below fair value price.

nachi (1990) the traded security in such a market would be free from idiosyncratic risk and vulnerable only to systematic risk.

The pool-specific market—the stipulations (STIPs) market—is an important alternative to trading Freddie Mac PCs. In this market, pool specific information is available on the identity of the mortgage originator, and, more recently, borrower credit scores, the geographic composition of the pool, loan-to-value ratios, and pool termination histories.[12] In theory, PC prices should impound all of the known factors that determine the expected cash flows of the pools. Presumably, traders who could achieve the most accurate predictions of future cash flows would be at an informational advantage in the STIPs market.

2.3 The REMIC Market

The multi-class MBS, or "REMIC", market is another important source of demand for PCs.[13] As noted earlier, an important benefit of the multi-class structure is that some of the classes can be assigned higher priority claims on the underlying mortgage cash flows, rendering the MBS cash flows relatively more predictable even if the underlying pools exhibit termination rates that fluctuate substantially through time. The single-class PCs that underlie Freddie Mac's REMIC securities are contributed by investment banks and Freddie Mac from their respective inventories. In exchange they obtain pro-rata shares of the REMIC securities. Freddie Mac also earns a fee for its work in creating the multi-class security, and the investment banks profit if the aggregate value of the multi-class security exceeds the value of the single-class PCs from which it was created.[14]

In Figure 2, we plot the breakdown of unseasoned PC balances backing multi-class (REMIC) and single-class (non-REMIC) MBS.[15] The outstanding share of PC balances that were held in non-REMICs grew dramatically starting in 1997. As can be seen by comparing figures 1 and 2, the relative decrease in the outstanding proportions of PCs that were securitized into REMICs is coincident with the rise in Freddie Mac's purchases of PCs for its retained portfolio. The share of REMIC to non-REMIC principal converged in late 2002, largely due to the very rapid payout rates on the non-REMIC collateral.

[12]Pool-specific informtion on credit scores and the loan-to-value distibutions for the pools were not made available before June of 2003

[13]The acronym "REMIC" refers to Real Estate Mortgage Investment Conduit, a special legal structure used to issue structured MBS; the term "collateralized mortgage obligation" or "CMO" often refers to the same legal structure. Henceforth we use the terms REMIC and multi-class MBS interchangeably.

[14]This requires that the markets be initially incomplete, in the sense that the cash flow patterns offered by the multi-class security did not previously exist in the market. See Oldfield (2000) for a further discussion of how value is added by the creation of multi-class securities.

[15]Many PC pools had fractions of their overall principal balance allocated to REMICs and many PC pools were fractionally allocated to a number of different REMICs. We assigned all of these fractional principal allocations to their respective REMIC and non-REMIC market segments.

Table 3 summarizes Freddie Mac's 2003 mortgage-related holdings. As shown, $472 billion, or 29 percent, of the total issued Freddie Mac PCs have been converted into structured multi-class REMICs. Freddie Mac held in its own retained portfolio 34 percent of the total issued single-class PCs and 26 percent of the total issued REMICs. The fact that Freddie Mac holds REMICs despite its likely superior knowledge of mortgage termination trends is consistent with the theory of pooling and tranching outlined at the outset (DeMarzo and Duffie (1998)). Superior termination information in the REMIC market can be used to more accurately value the subordinate REMIC classes in which most of the termination risk resides; since Freddie Mac is the better informed agent, it is likely that they hold these subordinate classes. Unfortunately, we do not have information concerning where in each REMIC bond structure Freddie Mac concentrates its purchases, so this conjecture cannot be verified.

As noted above, Freddie Mac and the investment banks receive prorated shares of newly created REMICs. However, the shares depend on the principal value, and not the market price, of the single-class PCs they contribute to the pool of PCs backing the REMIC securities. There is thus a strong incentive for each firm to provide only low value PCs as their contribution to the underlying pools. To be sure, other factors will also enter into the decision of which PCs to contribute. For example, this procedure provides a convenient outlet for the investment banks to sweep their inventory of small bits and pieces of PCs into REMIC pools, which otherwise would have to be sold at a discounted price as odd lots. In any case, the outcome is that the single-class PCs used to create REMICs are likely to be lemons relative to the PCs that are not used for this purpose. In the next section, we will consider the degree to which pools selected to back REMICs are, in fact, lemons.

3 Are Multi-Class MBS Lemons?

An important feature of the Freddie Mac PC market is that the true quality of all PCs can be known *ex post* due to the registration requirements and reporting conventions of the securitized mortgage bond market. Freddie Mac provides publicly available information on the termination speeds of all Freddie Mac PCs at the end of every month. It also provides registration reports on the *cusips* for PC pools that are included in REMICs.[16]. A possible concern is that the timing of these reporting practices might allow the GSE's and the commercial banks to exploit private information on termination speeds. For example, this information could be used to identify which pools *should* be allocated to the REMIC market rather retained for portfolio investment.

[16]This usually occurs several months after the origination of the individual PC pools

We identify two channels for informed agents to exploit information asymmetries in the PC market. A *tactical selection channel* is associated with market timing and exploiting the short-run persistence of termination speeds. The tactical selection channel enables informed agents to identify and reject lemon pools using pool-specific termination speeds that are known before other agents in the market.[17] The tactical selection channel operates through short-run timing effects at pool origination. Informed agents exploit early arriving information on the initial termination experience of PC pools to forecast future cumulative termination speeds. For this channel to be a viable mechanism, a pool's early termination speed must be persistent enough to reliably forecast the later termination speed of the pool.

A *strategic selection channel* is associated with the commercial banks' and Freddie Mac's modelling expertise in long-run forecasting of termination speeds at the pool-level. This channel requires informed agents to identify lemons *ex ante*. Lemon PCs are those expected to have slow long-run termination speeds in rising interest-rate environments (their weighted average coupons are below the current mortgage rate) and fast long-run termination speeds in falling interest-rate environments (the weighted average coupon is above the current mortgage rate). Pools such as these would then be allocated to the REMIC market where their elevated termination risk can be re-engineered into less risky senior bonds (suitable for uninformed low-yield investors) and risky subordinated bonds (suitable for informed high-yield investors). Pools that are expected to return principal rapidly in rising interest-rate environments, and vice-versa, would be considered non-lemons and would be held directly.

3.1 Reduced-Form Analysis

We test for the existence of the tactical and strategic selection channels by regressing the cumulative terminations of PC pools on an *ex ante* measure of initial terminations for the tactical channel and a contemporaneous measure of cumulative interest-rate changes for the strategic channel.[18] We also include a number of other controls for publicly available

[17]Recent testimony by Armando Falcon Jr., director of the Office of Federal Housing Enterprise Oversight, suggested that "...Fannie Mae was performing a sorting and sifting process involving actual scoring of trades that allowed the enterprise to retain high quality loans for its portfolio while fulfilling matched buy-and-sell trades using lower quality collateral. The enterprise referred to this process internally as "keep the best; sell the rest"." *Inside MBS & ABS* April, 8, 2005. The Wall Street Journal (April 7, 2005) also reported that the GSE regulator, Mr. Falcon, stated that, ".. Fannie's policy allowed it to wait until the end of the month in which a transaction is settled to decide whether to sell or hold a given security," which is in violation of generally accepted accounting principles. A 2003 internal report completed by Baker, Botts LLP also reported that "...Freddie's MBS trading unit routinely identified the best securities for the company's investment arm." *Inside MBS & ABS*, April, 8, 2005.

[18]The mortgages that appear in the pools we focus on are fully amortizing, which means that at the end of their scheduled 30-year terms, the remaining balance on each mortgage is zero, assuming no prepayment, default, or early payments of principal (curtailments). Each month, the mortgage payment is constant, implying that the relative shares of interest and principal in the total payment are changing each month.

information, such as the pool's weighted average origination coupon, the financial institution that originated the mortgages, time dummies for vintage effects, and the cumulative changes in the ten-year Treasury rate over the given holding period. We focus on comparisons of "pure" REMIC pools, where 100 percent of the principal is in REMIC, with pure non-REMIC pools where none of the principal has been re-securitized.

Table 4 provides some summary statistics for the variables that we use in our reduced-form analysis. The tactical channel is identified as cumulative unscheduled mortgage terminations (prepayments and defaults) over the first three months of a pool.[19] The average three-month cumulative termination rate is 1.3 percent of the original pool balance, with a range from zero to 89 percent, and the standard deviation is quite large, indicating that some pools "burn out" very rapidly while others experience very little in the way of terminations over the first three months. The cumulative termination rates over the longer horizons exhibit a similar high degree of dispersion, and the average cumulative termination rate rises with the investment horizon, as it is natural to expect given how the variable is constructed.

The cumulative changes in the ten-year Treasury rate from the fourth month to the end of the holding period are a measure of the pool's exposure to fluctuating Treasury rates given both the pool vintage and the investment holding period. As shown in Table 4, the mean of this variable becomes more negative as the holding period increases, reflecting the fact that, in general, Treasury rates were falling over the period of study. Like the cumulative termination rates, the standard deviations are quite large, reflecting the wide variation in the interest-rate experiences looking across the vintages of the pools.

We include in our sample only "pure" REMIC and non-REMIC pools—that is, pools that are either entirely or not at all devoted to REMIC re-securitizations. Under this strict definition, REMIC pools account for about 7 percent of the sample; in our restricted sample, REMIC pools make up about 40 percent of the pools. However, there is considerable variation in the share of REMIC pools over the vintages, as suggested by Figure 2. We also report the market shares of various mortgage originators. The shares are in general low, as there are many originators in that highly competitive segment of the residential mortgage market.

We report the reduced form regression results in Table 5. We find a positive and statistically significant effect of the cumulative initial termination rates on the subsequent cumulative termination experience for most investment horizons.[20] The statistical and economic

[19]Because Freddie Mac guarantees the Gold PCs against default, default events look like prepayments. It is important to emphasize that we *do not* include scheduled interest and principal payments in our measure; thus the dependent variable is thus one less the survival factor for each pool at each time horizon. See Bartlett (1989) for details on survival factors.

[20]It is important to note that here we are conditioning only on the first three months of termination history for each pool. We have also examined the predictive content of three-month average termination rates for future termination rates well after origination. These regressions indicate that, over short horizons, the most

importance of the tactical channel, however, appears to diminish over longer investment horizons. For the five year investment horizon, in particular, the short-term tactical advantage of knowing the early pool experience does not allow a statistically significant forecast for future termination rates, though sample-truncation may be an issue at this horizon. At the one-year horizon, the interaction of initial terminations with the REMIC indicator is positive and statistically significant. The interaction term is slightly negative and insignificant for the two-year horizon, but is negative and significant at longer horizons. These results indicate that the behavior of REMIC and non-REMIC pools is very different; positive initial terminations are a signal of faster speeds for REMIC pools over the one-year horizon, but much slower speeds, all else equal, later on, perhaps indicating that these pools tend to "burn out" more rapidly than the non-REMIC pools.

Increases in interest rates damp terminations at all horizons, as indicated by the negative and statistically significant coefficients on the contemporaneous cumulative changes of the ten-year Treasury rate. In general, the results also indicate that REMICs exhibit relatively slower termination speeds when Treasury rates are rising, and increases in speeds when Treasury rates are falling: the interactive effect of the REMIC designation with the cumulative Treasury changes is statistically significant and negative, except at the five year horizon where the coefficient is almost zero but statistically significant. These results suggest that a strategic selection channel also exists for REMIC investments and that this channel is operative over horizons out to about five years. We find that REMIC pools are lemons that return principal relatively slowly in rising rate environments and relatively rapidly in falling rate environments.

The other control variables reported in Table 5 indicate that higher weighted average coupon pools, everything else equal, terminate faster. There also appear to be significant termination heterogeneity across mortgage originators. It appears, for example, that Countrywide pools have statistically significantly higher cumulative termination speeds over most horizons and Suntrust originated pools have statistically significant slower termination speeds over the three through five year investment horizons. Finally, vintage effects are also important in these regressions but the patterns are not particularly informative; we have omitted these results for brevity.

In Table 6, we report the results of robustness checks for the specifications reported in Table 5. The purpose of these tests is to consider the effects of correlations among our selection measures. In Panel A, we first consider only the strategic channel controlling for the pool's weighted average coupon (WAC) and dropping the tactical channel from the specification.

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recent termination experience is a powerful predictor of future terminations. We have omitted these results for brevity.

All other aspects of the specification are identical to those used in the Table 5 regression. We find little change in our conclusions that REMIC pools tend to return principal more slowly when interest rates are rising and vice-versa.

Panel B of Table 6 shows that our results are largely unchanged when we focus strictly on the tactical selection channel again controlling for the pool's WAC. Again we find that the early termination experience of a pool is a statistically significant predictor of future speeds over all holding periods. The coefficient estimates on the interaction term are more negative at the longer holding periods, however, suggesting some correlation between the omitted cumulative Treasury variable and initial terminations. Comparing the adjusted-R^2 coefficients across Panels A and B, we see that the cumulative Treasury variable contributes significantly more to the fit than does the initial termination variable. This is to be expected given that the cumulative Treasury variable is a contemporaneous measure.

As a final robustness check, Table 7 presents sensitivity tests focusing on the effects of using different allocation rules to identify pools as either REMIC or non-REMIC. In Panel A of the Table, we consider an allocation rule where a pool is treated as REMIC if 75 percent of its original principal is re-securitized into REMIC, and non-REMIC if 25 percent or less of its balance is re-securitized. In Panel B, we report the results for a 95 percent cut-off rule. In every other way the specifications are identical to those in Table 5, although we do not report all the coefficient estimates in the interest of brevity. Here again, for both allocation rules we find statistically and economically significant tactical and strategic channels that both forecast rates and are differentiated by the REMIC status of Freddie Mac PCs. The 75 percent cutoff rule produces more consistent coefficient estimates: the initial termination interaction term is consistently negative and significant across the holding periods.

Although our reduced form regressions include a large number of covariates, the adjusted-R^2 values are relatively low and the forecasting accuracy of the specification is poor. The specification is particularly limited in controlling for the timing of terminations, the effect of house price dynamics on mortgage terminations, the interaction of default and prepayment on total termination levels, and the underlying economic structure of mortgage borrowers optimal option exercise policies. Controls for these effects require a richer structural modelling framework that accounts for the effects of rational expectations for future interest rates and house prices and that incorporates explicit controls for borrower-level frictions such as transaction costs and discrete decision-making. In the next section, we turn to such a model. Our purpose is twofold: to reveal that the REMIC designation of a pool is a significant causative factor in the market valuation of PCs, and to provide an estimate of the lemons discount on REMICs.

3.2 Structural Analysis

The valuation of mortgage-backed securities has been extensively studied in the finance literature. The models that have appeared in the literature to date can be differentiated by their treatment of the cash flows accruing to the holder of the mortgage-backed security. "Structural" models typically employ contingent-claims techniques to value the mortgage holders' option to prepay or default on the mortgage. In this framework, any cash flows in excess of scheduled principal and interest reflect the exercise of prepayment or default options by mortgage holders (see, for example, Kau et al. (1995), Stanton (1995), and Downing et al. (2005)). The structural approach has the advantage that the lines of causality between the state variables and investor behavior are clear.

3.3 Valuation Framework

We consider two primary sources of risk: interest rates and house prices. These variables enter our valuation equation as risk-factors, and as arguments to other explanatory variables that are essentially transformations of interest rates, house prices, and time, such as the time elapsed since the mortgage-backed security was issued, or the unpaid balance remaining in the underlying mortgage pool.

Interest Rates We assume interest rates are governed by the Cox et al. (1985) model,[21]

$$dr_t = (\kappa(\theta_r - r_t) - \eta r_t)dt + \phi_r \sqrt{r_t} dW_{r,t}, \tag{1}$$

where κ is the rate of reversion to the long-term mean of θ_r, η is the price of interest rate risk, and ϕ_r is the proportional volatility in interest rates. The process $W_{r,t}$ is a standard Wiener process.

We estimated the following parameters for the model using the methodology of Pearson and Sun (1989) and daily data on constant maturity 3-month and 10-year Treasury rates for the period 1968-1998:

$$\begin{aligned} \kappa &= 0.13131 \\ \theta_r &= 0.05740 \\ \phi_r &= 0.06035 \\ \eta &= -0.07577 \end{aligned}$$

[21] This model is widely used in the mortgage pricing literature. See, for example, Stanton (1995), and Kau et al. (1992).

House Prices The house price, H_t is assumed to evolve according to a geometric Brownian motion:

$$dH_t = \theta_H H_t dt + \phi_H H_t dW_{H,t}, \tag{2}$$

where θ_H is the expected appreciation in house prices, and ϕ_H is the volatility of house prices. Denoting the flow of rents accruing to the homeowner by q_H, after risk-adjustment house prices evolve according to:

$$dH_t = (r_t - q_H)H_t dt + \phi_H H_t dW_{H,t}. \tag{3}$$

We calibrate equation (3) as follows:

$$\begin{aligned} q_H &= 0.025 \\ \phi_H &= 0.085. \end{aligned}$$

The value of q_H is roughly consistent with estimates of owner-equivalent rents from the BEA, and we estimate the annualized volatility of housing returns from our data on house prices, discussed below. House prices and interest rates are assumed to be uncorrelated.[22]

Given these models for interest rates and house prices, standard arguments show that, in the absence of arbitrage, the value of the borrower's mortgage liability, $M^l(H_t, r_t, t)$, paying coupon c, must satisfy the partial differential equation:

$$\begin{gathered} \tfrac{1}{2}\phi_r^2 r M_{rr}^l + \tfrac{1}{2}\phi_H^2 H^2 M_{HH}^l + (\kappa(\theta_r - r) - \eta r)\, M_r^l + ((r - q_H)H_t)\, M_H^l + M_t^l - rM^l + \\ (\lambda_c + \lambda_p)\left(F(t)(1 + X_p) - M^l\right) + \lambda_d\left(H(1 + X_d) - M^l\right) + c = 0, \end{gathered} \tag{4}$$

where λ_c, λ_p, and λ_d are the state and time dependent hazards for seasoning, prepayment and default. We also need to impose boundary conditions. The first three of these are:

$$M^l(H, r, T) = 0, \tag{5}$$

$$\lim_{r\to\infty} M^l(H, r, t) = 0, \tag{6}$$

$$\lim_{H\to\infty} M^l(H, r, t) = C(r, t), \tag{7}$$

where $C(r,t)$ is the value of a callable bond with the same promised cash flows and same prepayment costs as the mortgage, but with no house price dependence.[23] Equation (5) is the terminal condition, reflecting the amortization of the mortgage. Equation (6) arises

[22] This assumption is made to simplify the interpretation of the results. In terms of solving the pricing problem and carrying out our econometric estimation below, it is straightforward to handle correlated house prices and interest rates.

[23] This value is calculated following the process described in Stanton (1995).

because all future payments are worthless when interest rates approach infinity, and equation (7) says that when the house price gets large, default no longer occurs, so we only have to worry about prepayment.

We need additional boundary conditions specifying the free boundary governing optimal default and prepayment. Prepayment is optimal when interest rates go below some (house price-dependent) critical level, $r^*(H,t)$, and default is optimal when the house price drops below some (interest rate-dependent) critical level, $H^*(r,t)$. At these boundaries, the mortgage value satisfies the conditions

$$M^l(H, r^*(H,t), t) = F(t)(1 + X_p), \tag{8}$$

$$M^l(H^*(r,t), r, t) = H^*(r,t)(1 + X_d). \tag{9}$$

Equation (8) states that, on the optimal prepayment boundary, the mortgage value is just equal to the remaining balance multiplied by 1 + the appropriate transaction cost. Equation (9) states that, on the default boundary, the mortgage is just equal to the value of the house multiplied by 1 + the default transaction cost.[24]

Solving equation (4) subject to these boundary conditions gives us the value of the borrower's liability, as well as the locations of the optimal default and prepayment boundaries, which in turn determine the values of the prepayment and default hazard rates, λ_p and λ_d. Given these values, we solve for the value of the investor's *asset*, M^a.

3.3.1 Option Exercise

The probability that borrowers exercise their options is described by hazard functions (Kalbfleisch and Prentice (1980), Cox and Oakes (1984)). Informally, if the hazard function governing some event is λ, then the probability that the event occurs in a time interval of length δt, conditional on not having occurred prior to t, is approximately $\lambda\,\delta t$. As noted earlier, borrowers might also be forced to prepay or default for nonfinancial reasons (such as divorce, job relocation, or sale of the house), which we assume is also described by some hazard function. We refer to this as the "background" hazard.

We assume that the probability of prepayment or default in any time interval is governed by the state- and time-dependent hazard function, λ. The value of λ depends on whether it is currently optimal for the borrower to default or prepay, which in turn is determined as part of the valuation of the mortgage. We model the overall hazard rate governing mortgage

[24]There are two additional "smooth-pasting" boundary conditions (see Merton (1973)), that ensure the optimality of the boundaries $r^*(H)$ and $H^*(r)$. Our solution algorithm follows Downing et al. (2005).

termination as:

$$\lambda(t) = \beta_1 + \beta_2 \text{atan}\left(\frac{t}{\beta_3}\right) P_t + \beta_4 \text{atan}\left(\frac{t}{\beta_5}\right) D_t \quad (10)$$

$$= \lambda_c + \lambda_p + \lambda_d, \quad (11)$$

where β_0 denotes the background hazard, the indicator variable P_t is one when prepayment is optimal at time t, and zero otherwise, and the indicator D_t is one when default is optimal, and zero otherwise. The atan function captures the idea of "seasoning" (see, for example, Richard and Roll (1989)), where *ceteris paribus* new loans terminate more slowly than older loans. In the prepayment region, the termination rate rises over time at a rate governed by β_2 to a maximum rate dictated by the value of β_3. Similarly, in the default region, termination rates rise at a rate governed by β_4 to a maximum given by β_5. For simplicity in what follows, we will use the notation given in equation (11) to refer to the hazard rates that apply in the various regions of the state space, where $\lambda_c \equiv \beta_1$, $\lambda_p \equiv \beta_2 \text{atan}\left(\frac{t}{\beta_3}\right) P_t$, and $\lambda_d \equiv \beta_4 \text{atan}\left(\frac{t}{\beta_5}\right) D_t$.

3.3.2 Transaction Costs and Borrower Heterogeneity

Under the structural modeling approach outlined above, mortgage terminations arise from the exercise of options by mortgage holders. Option exercise, however, usually involves both direct monetary costs, such as origination fees and mortgage closing costs, as well as implicit costs, such as the time required to complete the process. We model all of these via a proportional transaction cost, $X_p \geq 0$, payable by the borrower at the time of prepayment. Prepayment is optimal for the borrower if:

$$M_t^l \geq F(t)(1 + X_p). \quad (12)$$

Different borrowers might face different transaction costs. To account for this possibility, we assume that the costs X_p are distributed according to a beta distribution with parameters β_5 and β_6. This distribution is chosen because it can take many possible shapes, and is bounded by zero and one. Its mean and variance are:

$$\mu = \frac{\beta_5}{\beta_5 + \beta_6}$$

$$\sigma^2 = \frac{\beta_5 \beta_6}{(\beta_5 + \beta_6)^2 (\beta_5 + \beta_6 + 1)}$$

Like prepayment, defaulting incurs significant direct and indirect costs, such as the value of the lost credit rating. We model these costs via another proportional transaction cost, X_d, payable by the borrower at the time of default. Default is optimal for the borrower if:

$$M_t^l \geq H_t(1 + X_d). \tag{13}$$

For computational tractability, we assume that $X_d = 0.05$ (five percent of house value).

3.3.3 Structural Model Coefficient Estimates

We estimate the hazard parameters and the parameters of the transaction cost distribution following the methodology of Downing et al. (2005). In columns 2-3 of Table 8, we report the results for the sample of all Freddie Mac PCs issued over the period. We retain the restriction that the pools must contribute no principal to REMIC deals or be devoted entirely to REMIC; after these restrictions, our sample consists of 33,024 pools and 2,472,183 pool-month observations.

Since the sample size is very large, it is not surprising that all of the coefficient estimates are highly statistically significant. The parameter β_1 governs the background hazard rate, while β_2 and β_3 govern the time dependent seasoning component of the hazard rate. The estimate for β_1 indicates that approximately 0.06 percent of a pool's balance (at a monthly rate) is expected to be returned as a result of prepayments or defaults not predicted by movements in interest rates or house prices. The estimates for β_2 and β_3 show that the prepayment hazard rate rises from 1.75 percent after 3 months to 7.14 percent after five years.[25] The prepayment rate then rises more slowly to 7.7 percent by the end of the scheduled life of the pool. The estimates of β_4 and β_5 indicate that the default rate rises from 1.58 percent after three months to 11 percent after five years. The higher rate relative to prepayment indicates that, conditional on default being optimal, more borrowers do in fact default out of the pool. The default rate then rises slowly to 12.8 percent by the end of 30 year period.

The estimates of β_5 and β_6—the parameters determining the distribution of transaction costs in the borrower pool—indicate that the mean of the transaction cost distribution is about 15 percent of the remaining balance with a standard deviation of 12 percent. These results suggest that borrowers face important costs associated with mortgage refinancing and that there is considerable heterogeneity in these costs across borrowers in the pools.

Columns 4-5 display the estimation results for the REMIC subsample, and columns 6-7 display the results for the non-REMICs. As can be seen, the REMICs exhibit a slightly

[25] These figures mean that, after 3 months, conditional on prepayment being optimal according to the model, 1.75 percent of the pool balance will be returned per month as a result of prepayments.

slower pace of background terminations than the non-REMICs ($\beta_1 = 0.00367 < 0.00509$). Furthermore, the prepayment and default hazard rates are slower for the REMICs. Focusing first on prepayment rates, the hazard coefficients β_2 and β_3 indicate that, five years after origination, non-REMICs prepay at a rate of 9.7 percent of pool balance per month, while REMICs pay at a rate of only 7.6 percent. The non-REMIC prepayment rate reaches a maximum of 11.2 percent, while the REMIC prepayment rate reaches a maximum of only 8.3 percent.

Turning to the default hazards, characterized by the coefficient estimates β_4 and β_5, after five years the pace of defaults in non-REMIC pools is about 2 percentage points higher than in REMIC pools. This gap narrows to about 0.5 percentage points at the end of the scheduled thirty year term. As noted above, due to the principal guarantee of Freddie Mac, defaults generate a return of principal just like that of prepayments. For purposes of this paper, we assume that there is no probability that Freddie Mac will fail to honor its guarantee.

Finally, we consider the coefficients governing the distribution of transaction costs β_6 and β_7. The coefficient estimates indicate that the mean transaction cost in the REMIC sample is 14.8 percent with a standard deviation of 11.7 percent; in the non-REMIC sample the mean is 15.3 percent with a standard deviation of 12.5 percent. Hence the non-REMIC pools exhibit termination rates consistent with slightly higher transaction costs, offsetting some of the effects of the differential hazard rates discussed above. Nevertheless, on net the REMIC pools return principal more slowly than the non-REMIC pools on average over the sample.

To determine whether or not there is a statistically significant difference between the REMIC and non-REMIC coefficient estimates, we test the null hypothesis that $\beta_R = \beta_{NR}$, where β_R denotes the coefficient estimates for the subsample of REMIC pools and β_{NR} denotes the coefficient estimates for the subsample of non-REMIC pools. The test statistic is given by:

$$f = \frac{(\mathrm{SSR} - \mathrm{SSR}_R - \mathrm{SSR}_{NR})/p}{(\mathrm{SSR}_R + \mathrm{SSR}_{NR})/(N - 2p)},$$

where SSR denotes the sum of squared residuals from the regression:

$$y - \hat{y} = Jb + \epsilon.$$

Here y denotes the observed monthly termination rates, $\hat{y}$ the predicted termination rates, J the Jacobian of $\hat{y}$ evaluated at the estimated coefficients, and b is a nuisance vector of coefficients. Both $\hat{y}$ and J are computed at the coefficient estimates for the pooled sample. The terms SSR_R and SSR_{NR} denote the squared errors from the same regression where the sample is restricted to REMIC pools and non-REMIC pools, respectively. The statistic f

is distributed $F(p, N - 2p)$ under the null hypothesis. For the parameters below, the 95 percent critical value of the F-statistic is approximately two. See Davidson and MacKinnon (1993) and Gallant (1975) for more details on this specification test.

As shown in Table 9, we easily reject the null hypothesis that the market valuation models for REMIC and non-REMIC pools are equivalent and accept the alternative hypothesis that the market would value the two types of pools differently if a pool's *ex post* designation as REMIC were known *ex ante*. These results provide strong evidence that there is a missing factor in the valuation model and the factor is associated with whether or not a PC pool is re-securitized in the REMIC market.

Finally, it remains to estimate the economic implications of the speed differences that we have identified above. Unfortunately, as we discussed earlier, due to data limitations we cannot simply look at the relative prices of REMIC and non-REMIC pools to assess the lemons discount that the market applies to discounted REMIC pools. However, we can use our structural model to compare the estimated prices of otherwise identical pools as a way of estimating the magnitude of the lemons discount.[26]

We computed estimates of the lemons discount as follows. First, we matched REMIC and non-REMIC pools issued on the same date with exactly the same coupon. This reduced the sample to just 487 matched observations. We then subtracted the fitted non-REMIC new-issue price from the fitted REMIC new-issue price. The resulting lemons discount ranges from $-0.2 to $0.12 per hundred dollars of principal, with negative values (premia on REMIC pools relative to non-REMIC) when the MBS are priced to a premium, and positive values (discounts on REMIC pools relative to non-REMIC) when the MBS are priced at a discount, as expected. In order to make the presentation of these results more manageable, we regress the estimated lemons discounts on the 10-year Treasury rate and the difference between the weighted-average coupon and the Treasury rate. As can be seen in Table 10, these two factors explain 95 percent of the variation in lemons discounts (the remaining variation is due to the other components of the model that we have omitted, such as house prices). As noted earlier, as the spread between the coupon to the Treasury rate rises (the MBS is priced at a premium), the lemons discount falls. Holding the spread constant, a higher Treasury rate is correlated with lower lemons discounts; higher Treasury rates in our model are associated with flatter term structures under which the slow paying properties of the REMIC pools are less important.

In terms of yield-to-maturity, these results indicate differences of roughly 3-5 basis points

[26] As discussed in Downing et al. (2005), the structural model exhibits pricing errors on the order of a few percentage points when used to predict TBA prices. Because we are differencing prices across the REMIC and non-REMIC pools, we can expect these pricing errors to be cancel to the extent that the models exhibit similar pricing errors.

between the pools. Given the scale of the REMIC market, these differences are clearly economically meaningful. Nevertheless, we view these estimates as lower bounds, owing to some of the features of our model. First, in the model we assume that interest rates are generated according to a square-root diffusion process. As is well known, this process cannot capture the full range of term structures that are observed in practice. In particular, the upward-sloping term structure yet fairly steep downward movements in long-term rates that are observed in our sample are hard to capture in this model. Moreover, we are only able to capture the long-term average speed differences in pools under our model—it is an equilibrium model. Presumably a more flexible interest-rate process, would allow greater flexibility in the term structure process, and termination processes that reflect expectations for changes in long-term rates would enhance the ability of the model to price REMIC and non-REMIC pools.

4 Conclusions

In this paper, we have presented evidence indicating that the market for multi-class MBS is a market for lemon mortgage pools. Because the MBS market is characterized by a high degree of information asymmetry between key participants, a lemons discount would be applied to all of the pools sold by the informed players—the GSEs and investment banks that form the mortgage pools and market the MBS. In this situation, only low-quality MBS would be traded. However, as predicted by Akerloff (1970) and formalized in DeMarzo and Duffie (1998), the market has evolved a solution to this dilemma: the capital structures of multi-class MBS represent this market response, and indeed, as we show, lower-quality pools tend to end up backing multi-class MBS. The pricing of the multi-class securities can remain efficient because the lower tranches, which are most exposed to the termination behavior of the lemon pools, can be traded and priced efficiently by the informed traders. The upper tranches, which are insulated from the payment behavior of the mortgage pool, are traded by uninformed investors.

The markets for other types of structured financial products has exploded over the past ten years. Is the growth of these markets driven by a lemons discount on the underlying assets and an associated market response? For example, in the commercial mortgage sector, pooling and tranching are now used to fund a share of total outstanding mortgages that exceeds the share funded through insurance companies, traditionally one of the largest lenders to this sector. Given the similar information asymmetries in commercial and residential mortgage markets, it is plausible that at least part of the rapid growth in commercial mortgage-backed securities represents a market response to the lemons problem. One might also draw similar conclusions about credit-card backed, auto-loan backed, and other asset-backed securities where information asymmetries between the originators of the underlying assets and the final investors providing capital to the sector would otherwise invoke a lemons discount on the assets. Further research into this issue would likely be fruitful.

Recently, the GSEs have been accused of "cherry picking" MBS pools—using their superior information to identify lemon MBS pools. As is well known, the GSEs have access to monthly pool payment information before anyone else in the market. Our results confirm that this preferential access to monthly prepayment speeds could be highly useful in choosing specific pools to hold in a portfolio. We are not surprised, therefore, that the GSE regulators are finding direct evidence that the GSEs have used their inside information to "keep the best and sell the rest."[27] It should also be noted, however, that Freddie Mac likely faced a lemons discount on the PCs that it tried to sell; the efficiency of the prices of these PCs remains an open question.

[27]We have no direct evidence in this paper concerning the actual MBS and REMIC trading practices of Freddie Mac or Fannie Mae. Therefore we can offer no position on whether or not they have violated insider trading laws.

Table 1: Freddie Mac Participation Certificate Issuance by Product Type

This table displays the weighted average coupon (WAC) and number of pools securitized (N) each year for all Freddie Mac mortgage-backed securities issued between from 1991 through 2003. The weighted average coupons are displayed in percent.

	30 Year Gold PC		15 Year Gold PC		Balloons 5 or 7 Year		30 Year Gold Mini PCs		Total Pools	
Year	WAC	N	WAC	N	WAC	N	WAC	N	WAC	N
1991	9.66	5,154		0		0	9.76	24	9.66	5,181
1992	8.71	9,955		0		0	8.88	54	8.70	10,009
1993	7.67	10,235		0		0	8.17	9	7.60	10,244
1994	8.00	7,841		0		0	8.54	34	8.00	7,875
1995	8.24	3,247		0		0	8.41	4	8.24	3,251
1996	8.11	5,946		0	8.00	162	8.22	5	8.11	6,113
1997	7.76	4,821		0		0	7.71	4	7.75	4,825
1998	7.11	11,307		0		0	7.01	11	7.10	11,318
1999	7.66	4,145		0		0	7.79	74	7.66	4,219
2000	7.77	1,792		0		0	7.65	22	7.77	1,814
2001	6.89	6,687	6.36	2,878		0	6.75	48	6.72	9,623
2002	6.34	6,007	5.92	5,399		0	6.27	79	6.15	11,516
Total		77,173		8,277		162		368		85,988

Table 2: Summary Statistics for the Unseasoned Freddie Mac Participation Certificates Use in the Analysis

This table provides summary statistics for the unseasoned Freddie Mac Participation Certificate pools by year of origination. Unseasoned PCs are pools in which the weighted average remaining maturity is 356 or more months in the second pool-month.

Year	Weighted Average Coupon (%)	Weighted Average Remaining Term	Average Balance ($)	Number of Loans	Number of Pools
1991	9.56	357.67	3,830,853	148,962	4,120
1992	8.66	358.45	2,609,297	186,104	7,583
1993	7.68	358.63	4,248,574	360,412	9,055
1994	8.07	358.93	5,947,965	424,959	7,099
1995	8.28	358.77	6,222,346	180,975	3,040
1996	7.98	358.53	7,963,095	282,777	3,826
1997	7.76	358.60	10,295,661	408,768	4,590
1998	7.07	358.19	15,510,182	870,591	6,987
1999	7.77	358.75	9,757,444	262,048	3,286
2000	7.75	359.04	13,765,590	150,153	1,586
2001	6.87	358.78	21,175,188	858,725	6,217
2002	6.42	358.39	27,575,688	776,150	4,540
Total				4,910,624	61,929

Table 3: Freddie Mac Mortgage Related Securities Outstanding, Year-End 2003

This table compares Freddie Mac's portfolio holdings of single and multi-class mortgage backed securities created from Freddie Mac Participation Certificates to the total issuance of these securities in the United States.

Total Issuance			Retained by Freddie Mac			
\$ Billion		REMIC	\$ Billion		% of Class Total	
PCs	REMIC	Share	PCs	REMIC	PCs	REMIC
1,162	472	29	393	124	34	26

Table 4: Summary Statistics for the Reduced Form Regressions

Variable	Mean	Standard Deviation	Min.	Max.
One year holding period or less				
Cumulative changes 10 Yr. Treas. rate (Over Month 4 – 16)	-0.124	9.962	-18.450	20.700
Cumulative termination rate (Over Month 4 – 16)	0.137	0.135	0	0.8831
Two year holding period or less				
Cumulative change 10 Yr. Treas. rate (Over Month 4 – 28)	-2.169	19.207	-36.450	34.300
Cumulative termination rate (Over Month 4 – 28)	0.293	0.221	0	0.968
Three year holding period or less				
Cumulative changes 10 Yr. Treas. rate (Over Month 4 – 40)	-5.743	26.512	-59.920	46.000
Cumulative termination rate (Over Month 4 – 40)	0.389	0.238	0	0.9709
Four year holding period or less				
Cumulative changes 10 Yr. Treas. rate (Over Month 4 – 52)	-11.641	34.496	-85.870	57.920
Cumulative termination rate (Over Month 4 – 52)	0.496	0.245	0	0.9793
Five year holding period or less				
Cumulative changes 10 Yr. Treas. rate (over Month 4 – 64)	-18.416	39.173	-112.330	57.860
Cumulative termination rate (Over Month 4 – 64)	0.571	0.2404	0	0.9796
Variables that do not change with holding period				
Initial termination rate (Months 1 to 3)	0.013	0.035	0	0.889
Origination WAC (%)	7.74	0.860	5.75	9.875
Remic	0.407	0.491	0	1
ABN AMRO	0.07	0.10	0	1
Countrywide	0.07	0.31	0	1
Washington Mutual	0.11	0.31	0	1
Chase	0.07	0.26	0	1
Flagstar	0.04	0.21	0	1
Bank of America	0.02	0.14	0	1
Suntrust	0.02	0.15	0	1
USBank	0.02	0.13	0	1
Accubanc	0.04	0.19	0	1
Resource Mort. Grp.	0.01	0.12	0	1
Crossland	0.03	0.18	0	1
Wachovia	0.03	0.16	0	1
Bishops	0.02	0.12	0	1
N=33,024 mortgage pools				

Table 5: Reduced Form Regression Results

The table displays coefficient estimates from regressions of pool-level cumulative termination rates on the weighted-average origination coupon for each pool, the cumulative change in the ten-year Treasury rate over the indicated horizon and its interaction with a dummy variable for pools with 100% allocation to REMIC, and the cumulative terminations over the first three months from the origination of a pool, also interacted with the REMIC dummy. Coefficient estimates on the dummy variables for pool origination vintage are available upon request.

	Horizon (Years)									
	One		Two		Three		Four		Five	
	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.
Pool Origination WAC	0.018***	0.0001	0.038***	0.0002	0.049***	0.0002	0.060***	0.0002	.069***	0.0002
Initial Terminations (Months 1 to 3)	0.327***	0.0228	0.111***	0.0344	0.171***	0.0354	0.185***	0.0356	-.050	0.0347
Initial Terminations × REMIC	0.162***	0.0438	-0.066	0.0662	-0.564***	0.0691	-1.097***	0.0696	-.986***	0.0676
Cumulative Changes 10 Yr. Treas. Rate (From Month 4)	-0.0004***	0.0001	-0.0023***	0.0001	-0.002***	0.0001	-0.002***	0.00004	-0.002***	0.00004
Cumulative Treas. × REMIC	-0.004***	0.0002	-0.003***	0.0001	-0.001***	0.0001	-0.0005***	0.00007	0.0004***	0.00005
INSTITUTIONAL FIXED EFFECTS										
ABN AMRO	0.056***	0.0029	0.042***	0.0045	0.021***	0.0047	-0.003	0.005	-0.036***	0.0059
Countrywide	0.013***	0.0033	0.022***	0.0049	0.052***	0.0051	0.121***	0.005	0.141***	0.005
Washinton Mutual	-0.003	0.0043	-0.007	0.0064	0.046***	0.0067	0.114***	0.007	0.136***	0.0065
Chase	-0.007**	0.0030	-0.019***	0.0045	-0.006	0.005	0.026***	0.0047	0.037***	0.0047
Flagstar	0.016***	0.0047	0.014***	0.0071	0.054***	0.007	0.101***	0.007	0.102***	0.007
Bank of America	-0.019***	0.0047	-0.003	0.0071	-0.016***	0.007	-0.045***	0.0075	-0.075***	0.007
Suntrust	0.001	0.0052	-0.006	0.0078	-0.049***	0.008	-0.076***	0.0084	-0.089***	0.0081
USBank	0.099***	0.0057	0.067***	0.0086	0.0302***	0.009	0.006	0.0092	-0.023***	0.0089
Accubanc	0.028***	0.0058	0.043***	0.0089	0.102***	0.0091	0.185***	0.0092	0.190***	0.0090
Resource Mort. Grp.	-0.014**	0.0067	-0.027	0.0101	0.077***	0.0107	0.132***	0.0107	0.137***	0.0133
Crossland	0.0012	0.0058	-0.0135	0.0087	0.028***	0.0090	0.101***	0.0092	0.112***	0.009
Wachovia	0.007	0.007	-0.004	0.0113	0.013	0.0116	0.0133***	0.0116	0.193***	0.0113
Bishops	0.0782***	0.0066	0.113***	0.0100	0.109***	0.0106	0.084***	0.0106	0.037***	0.0103
N	33,024		33,024		33,024		33,024		33,024	
Adj.-R^2	0.14		0.27		0.30		0.32		0.33	

*** Statistically significant at the 1% level or better.
** Statistically significant at the 5% level or better.
* Statistically significant at the 10% level or better.

Table 6: Robustness Tests for Reduced Form Regressions

The table reports results for regressions identical to those in table 5 above, except that in Panel A we omit the cumulative termination variable and it interaction with the REMIC dummy, and in Panel B we omit the cumulative change in the Treasury rate variable and its interaction term.

	Horizon (Years)									
	One		Two		Three		Four		Five	
	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.
Panel A: Omit Cumulative Terminations										
Pool Origination WAC	0.0182***	0.00015	0.0379***	0.00018	0.0491***	0.00018	0.0595***	0.00018	0.0686***	0.00018
Cumulative Changes 10 Yr. Treas. Rate (From Month 4)	-0.0003*	0.00013	-0.0023***	0.00010	-0.0024***	0.00006	-0.0020***	0.00005	-0.0016***	0.00003
Cumulative Treas. × REMIC	-0.0038***	0.00016	-0.0029***	0.00012	-0.0014***	0.00009	-0.0005***	0.00007	0.0004***	0.00005
N	33,024		33,024		33,024		33,024		33,024	
Adj.-R^2	0.135		0.271		0.299		0.324		0.331	
Panel B: Omit Cumulative Treasury Changes										
Pool Origination WAC	0.0175***	0.0001	0.0391***	0.0002	0.0511***	0.0002	0.0629***	0.0002	0.0731***	0.0002
Initial Terminations (Months 1 to 3)	0.3281***	0.0234	0.1098***	0.0367	0.1658***	0.0380	0.1808***	0.0377	-0.0748**	0.0358
Initial Terminations × REMIC	-0.0330	0.0447	-0.6022***	0.0700	-1.1396***	0.0736	-1.6025***	0.0732	-1.3172***	0.0695
N	33,024		33,024		33,024		33,024		33,024	
Adj.-R^2	0.098		0.171		0.194		0.248		0.291	

*** Statistically significant at the 1% level or better.
** Statistically significant at the 5% level or better.
* Statistically significant at the 10% level or better.

Table 7: Robustness Checks for Reduced Form Regressions: Sensitivity to REMIC sample definition

The table reports results for regressions identical to those in table 5 above, except that we consider alternative cutoff rules to identify REMIC pools. In Panel A we consider pools as REMIC if at least 75% of the pool has been re-securitized as REMIC and in Panel B we use a 95% cut-off rule.

	Horizon (Years)									
	One		Two		Three		Four		Five	
	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.	Coef. Est.	Std. Err.
Panel A: Selection Rule: 75% of Pool										
Pool Origination WAC	0.0176***	0.0001	0.0396***	0.0001	0.0504***	0.0001	0.0606***	0.0001	0.0702***	0.0001
Initial Terminations (Months 1 to 3)	0.4322***	0.0195	0.1856***	0.0299	0.2174***	0.0303	0.2538***	0.0299	-0.0158	0.0288
Initial Terminations × REMIC	-0.0932***	0.0325	-0.3165***	0.0498	-0.6721***	0.0510	-1.0923***	0.0502	-0.9256***	0.0484
Cumulative Changes 10 Yr. Treas. Rate (From Month 4)	-0.0002**	0.0001	-0.0021***	0.0001	-0.0021***	0.0001	-0.0017***	<0.0001	-0.0014***	<0.0001
Cumulative Treas. × REMIC	-0.0032***	0.0001	-0.0030***	0.0001	-0.0018***	0.0001	-0.0008***	<0.0001	0.0002***	<0.0001
N	54,419		54,419		54,419		54,419		54,419	
Adj.-R^2	0.136		0.276		0.300		0.317		0.316	
Panel B: Selection Rule: 95% of Pool										
Pool Origination WAC	0.0176***	<0.0001	0.0396***	0.0001	0.0507***	0.0002	0.0605***	0.0001	0.0696***	0.0002
Initial Terminations (Months 1 to 3)	0.3858**	0.0214	0.1259***	0.0322	0.1797***	0.0327	0.2364***	0.0323	-0.0054***	0.0311
Initial Terminations × REMIC	0.0430	0.0367	-0.1404**	0.0554	-0.5549***	0.0570	-1.0302***	0.0563	-0.8962***	0.0542
Cumulative Changes 10 Yr. Treas. Rate (From Month 4)	-0.0002	0.0001	-0.0019***	0.0001	-0.0021***	0.0001	-0.0017***	<0.0001	-0.0014***	<0.0001
Cumulative Treas. × REMIC	-0.0034***	0.0001	-0.0034***	0.0001	-0.0020***	0.0001	-0.0009***	0.0001	0.0001***	<0.0001
N	46,081		46,081		46,081		46,081		46,081	
Adj.-R^2	0.132		0.291		0.315		0.333		0.331	

*** Statistically significant at the 1% level or better.
** Statistically significant at the 5% level or better.
* Statistically significant at the 10% level or better.

Table 8: Structural Model Estimation Results

The table displays the nonlinear least-squares estimates of the coefficients of the structural model. The coefficient β_1 summarizes termination speeds when continuation of the mortgage is optimal. When a mortgage is in the region of the state-space where prepayment is optimal, the relevant hazard rate is determined by: $\lambda_p = \beta_2 \text{atan}(t/\beta_3)$, where t is the number of months since the mortgage was originated. When default is optimal, the hazard rate is determined by: $\lambda_d = \beta_4 \text{atan}(t/\beta_5)$. The coefficients β_6 and β_7 define the transaction cost distribution; the mean transaction cost is given by $\beta_6/(\beta_6 + \beta_7)$. The "Pooled" model is estimated on 33,024 pools that are either wholly or not at all devoted to REMIC deals. The time period is 1991-2002. The pools are clustered into 34 coupon groups distributed over a grid from a minimum coupon of 5.75% up to 9.875%, where the increment between each coupon group on the grid is 12.5 basis points. The All PC sample is further sub-divided into two pieces: the REMIC subsample, defined as pools devoting all of their principal to REMIC deals, and the non-REMIC pools subsample, defined as those pools that contribute no principal to REMIC deals. The REMIC model is estimated on 13,430 pools on the same grid of coupon rates as the full sample; the non-REMIC subsample is estimated on the balance of the pools.

	Pooled		REMIC		non-REMIC	
Coefficient	Estimate	Std. Err.	Estimate	Std. Err.	Estimate	Std. Err.
β_1	0.00671	0.000113	0.00367	0.000160	0.00509	0.000204
β_2	0.62087	0.000187	0.67149	0.000326	0.93396	0.000448
β_3	0.70476	0.000728	0.81653	0.001334	1.32454	0.001369
β_4	1.07795	0.002935	1.07208	0.003740	1.07067	0.016081
β_5	1.39438	0.008705	5.45943	0.023449	3.47181	0.071916
β_6	1.18825	0.000569	1.21965	0.000920	1.12412	0.000804
β_7	6.77311	0.002375	7.04153	0.003731	6.21016	0.003073
χ^2	84.2		60.1		59.0	
N	2,439,538		1,298,630		1,140,908	

Table 9: Chow Test Results

The table displays the results of the test of the null hypothesis that $\beta_R = \beta_{NR}$, where β_R denotes the coefficient estimates for the subsample of REMIC pools, and β_{NR} denotes the coefficient estimates for the subsample of non-REMIC pools. The test statistic is given by:

$$f = \frac{(\text{SSR} - \text{SSR}_R - \text{SSR}_{NR})/p}{(\text{SSR}_R + \text{SSR}_{NR})/(N - 2p)},$$

where SSR denotes the sum of squared residuals from the regression:

$$y - \hat{y} = Jb + \epsilon,$$

where y denotes the observed monthly termination rates, $\hat{y}$ the predicted termination rates, J the Jacobian of $\hat{y}$ evaluated at the estimated coefficients, and b is a nuisance vector of coefficients. Both $\hat{y}$ and J are computed at the coefficient estimates for the pooled sample. The terms SSR_R and SSR_{NR} denote the squared errors from the same regression where the sample is restricted to REMIC pools and non-REMIC pools, respectively. The statistic f is distributed $F(p, N-2p)$ under the null hypothesis. For the parameters below, the 95 percent critical value of the F-statistic is approximately two. See Davidson and MacKinnon (1993) and Gallant (1975) for more details on this specification test.

Element	Value
SSR	6,952.5
SSR_R	3,479.2
SSR_{NR}	3,470.4
p	7
N	2,407,239
f	144.81

Table 10: Regression of Lemons Discounts on Interest Rates

The table displays the results of the regression

$$LD_t = \beta_0 + \beta_1 \text{T10}_t + \beta_2 \text{Spread}_t + \epsilon_t$$

where LD_t is the lemons discount estimate on date t produced by the structural model, $T10$ is the 10-year Treasury rate on date t and Spread is the spread between the weighted average coupon on REMIC and non-REMIC pools on date t. The regression is carried out on 487 matched observations of REMIC and non-REMIC pools originated with the same coupon on the same date. The average of LD over the sample is $\$-0.064$ per \$100 of principal; the average of the positive lemon premia is \$0.039 per \$100 of principal. The sample average of T10 is 6.068, and the sample average Spread is 1.596, both measured in percentage points.

Variable	Coef. Est.	Std. Err.
Intercept	0.356	0.0045
T10	-0.041	0.0006
Spread	-0.106	0.0013
N = 487		
Adj.-R^2 = 0.95		

Figure 1: Ownership of Freddie Mac PCs

The vertical bars in the figure display the dollar amount by year of origination of PCs sold (light bars) and held (dark bars) by Freddie Mac. The solid line shows the ratio of PCs held to the total amount of PCs outstanding, and is to be read against the percentages on the right axis.

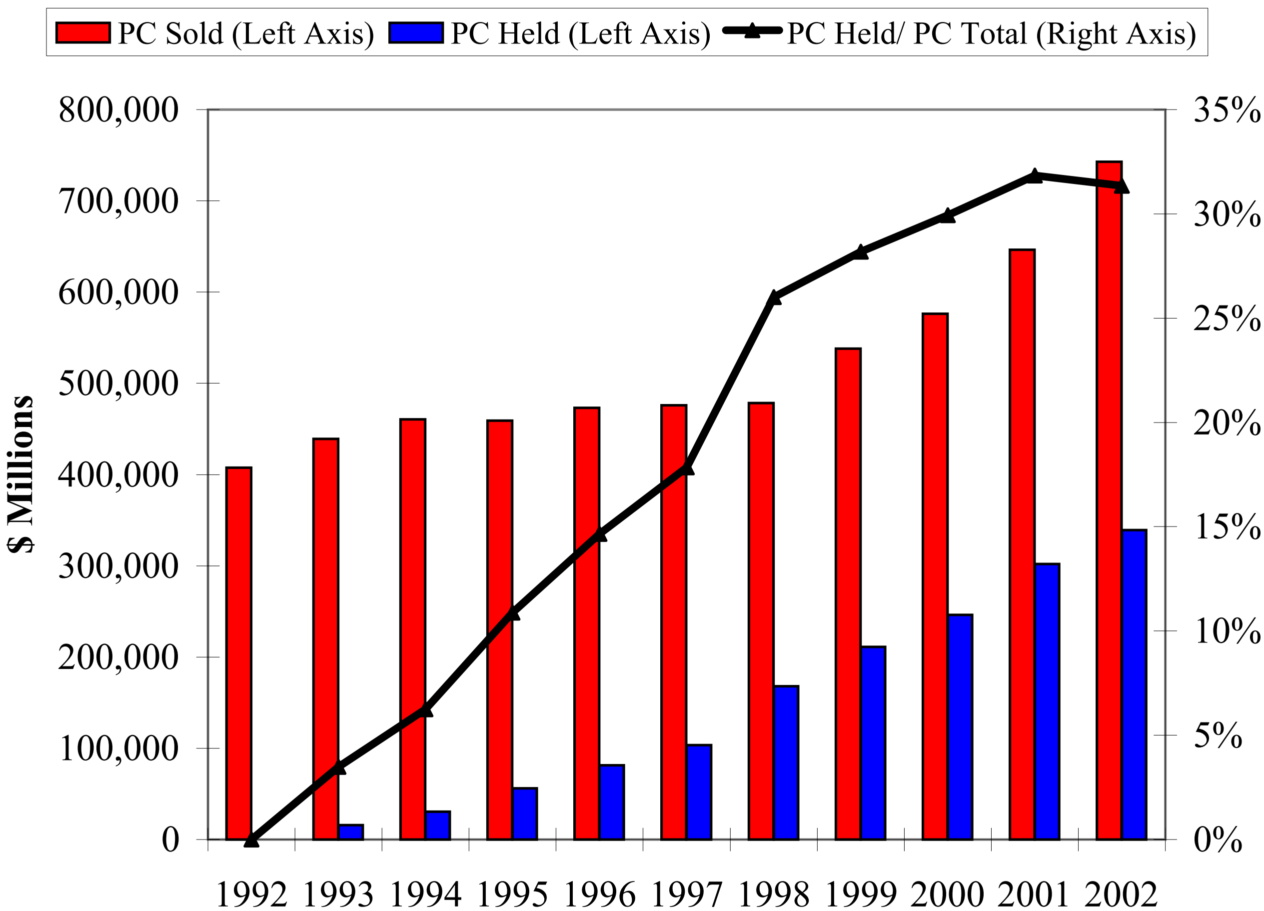
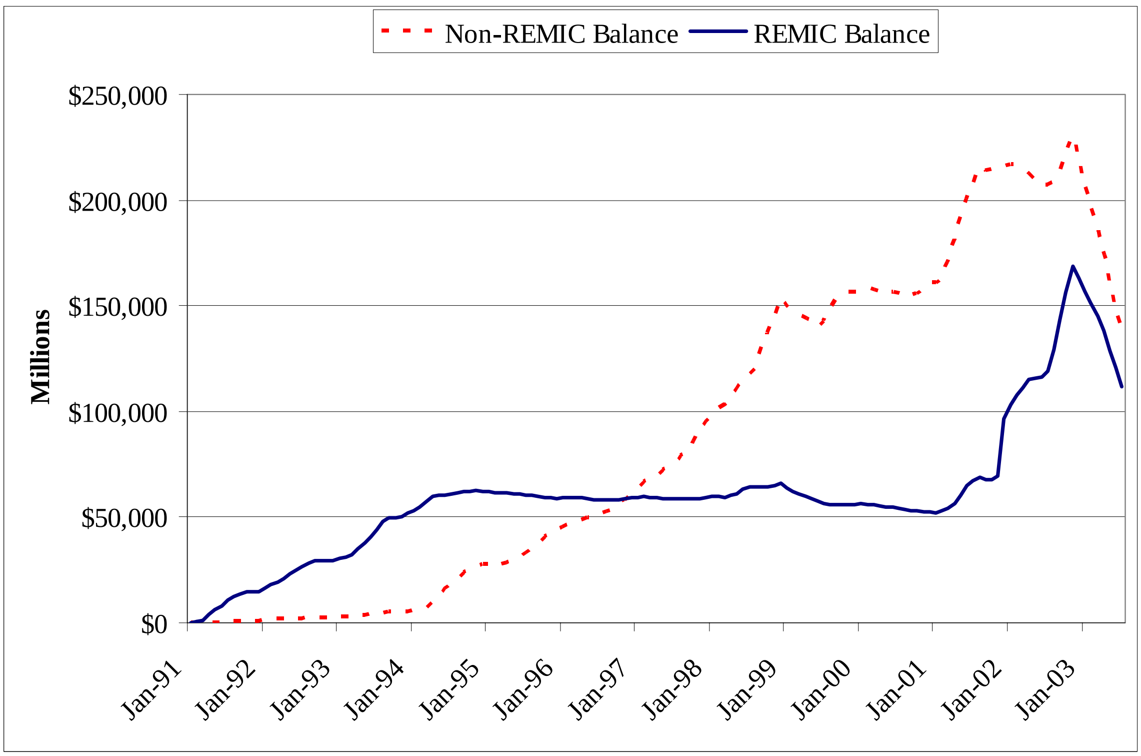


Figure 2: Outstanding Balances of Freddie Mac PC's held in REMIC and NONREMIC Structures

The figure plots the outstanding balances of unseasoned Freddie Mac PCs that back REMIC securities (solid line) and non-REMIC securities (dashed line). The calculations are made for the 61,929 unseasoned pools displayed in table 2 above.



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