Residential Mortgages: Prepayments and Prepayment Modeling

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- The goal of this primer is to provide an introduction to the different sources and motivations for prepayments along with a discussion of typical "patterns" we see in prepayment behavior. Along the way, we provide an explanation of the shorthand commonly used by market participants to describe these patterns in prepayment behavior such as the "lock-in effect", "seasoning ramp", "S-curve", "burnout", "media effect" and others.
- A prepayment can be defined as the unscheduled payment of mortgage principal by the borrower and can occur for a number of different reasons: home sales (turnover), refinancing, curtailment and default. The importance of prepayments stems from the value of the homeowner's right to prepay their mortgage at any time. As a result of this right, the investor in an MBS is effectively long a non-callable bond with the same payment schedule as the MBS and short a put and call option. Thus, being able to forecast prepayments plays an integral role in determining the risk/return profile of a mortgage-backed security.
- The key to understanding homeowner prepayment behavior and being able to forecast prepayments lies in determining the different causes of prepayment and the differing motivations for these causes. Therefore, we provide a through discussion and analysis of turnover, refinancing, curtailments and defaults. We also provide a brief overview of how prepayment models are built and conclude with an examination of the uses and limitations of prepayment models.

I. INTRODUCTION

What drives homeowners to prepay their mortgages? Broadly speaking, the difficulty in answering this question arises from the inherent complexity involved in understanding how a typical household values the complex bundle of rights and obligations that come along with a mortgage. In addition to mortgage rates, some of the factors that play a role in the prepayment decision include home values, the wealth of the borrower, their employment status, their income prospects, their age, the size of their family etc. Additionally, since a mortgage is just one line item in a household's "balance sheet" which will generally consist of a number of assets (mutual funds, stocks, housing) and liabilities (credit cards, mortgages, other loans), the decision to prepay the mortgage will also be influenced by the composition of this balance sheet. For example, a homeowner carrying high coupon credit card debt may be more motivated to refinance their mortgage and use it as a vehicle for debt consolidation. Unfortunately, the hurdles in understanding homeowner prepayment behavior are raised by the fact that in most prepayment data sets we do not have access to all the household-level data that could potentially influence the prepayment decision.

Still, the problem is not intractable because of the availability of a large data set that stretches back to the late 1970s/early 1980s on homeowner prepayment rates. A large number of mortgages have been securitized in mortgage-backed securities (MBS) over this time period and prepayment rates on these MBSs constitute the source for all of our prepayment data. Correlating prepayment rates on MBS with interest rates, home prices, and characteristics of the loans backing the MBS allows us to grasp many of the forces driving the prepayment behavior of homeowners.

The goal of this primer is to provide an introduction to the different sources and motivations for prepayments along with a discussion of typical "patterns" we see in prepayment behavior. Our discussion is largely qualitative and seeks to give users a feel for the multi-faceted nature of homeowner prepayment behavior. Although, in the process of discussing the data, we implicitly or explicitly mention some of the explanatory factors used in our prepayment model or illustrate the response functions of the prepayment model, our emphasis in this primer is providing the reader with solid intuition for why prepayment rates vary the way they do, and we do not delve into the technical details of how a prepayment model is built in practice.

The plan of this paper is as follows. To understand the themes underlying homeowner mortgage prepayment behavior we begin by defining what a prepayment is and by describing the different ways that homeowners can prepay their mortgages. Next, we provide an explanation for why prepayments play such an integral role in determining the risk/return profile of a mortgage-backed security (MBS). After this, we provide a guided tour of the conventions used for quoting and measuring prepayment rates. Before we get into some of the minutiae associated with understanding homeowner prepayment behavior, we walk through a detailed example to understand some of the typical patterns we see in homeowner prepayment behavior. The next step is to delve into the individual components of prepayment behavior (home sales, refinancing, curtailments and defaults) and discuss their causes. Our discussion then wraps up by going into a general outline of how prepayment models are built and validated. A concluding section examines the uses and limitations of prepayment models.

II. WHAT IS A PREPAYMENT?

A mortgage comes equipped with a repayment schedule which establishes a sequence of monthly payments[1] through which homeowners can payoff their debt. A **prepayment** is any activity by the homeowner that accelerates this schedule and extinguishes the mortgage before its final payment date. In the U.S., homeowners have the right to prepay their mortgage at any point in time, although there are transaction costs associated with this activity.[2]

To understand some of the nuances associated with the definition of prepayments, it is useful to think about the homeowner's choices when the monthly payment on their mortgage comes due. In this situation, they have the following mutually exclusive options:

1. Make the scheduled monthly payment; or
2. Payoff the mortgage in full; or
3. Send more than the scheduled monthly payment; or
4. Not make the scheduled monthly payment.

Options 2 through 4 would all be classified as a prepayment. Option 2 corresponds to situations where the homeowner sells a mortgaged house or refinances an existing mortgage; Option 3 is called a **curtailment** or a partial prepayment; and Option 4 is called a **default** or **involuntary prepayment**. We now explore some of the details associated with these different types of prepayments.

Home Sales

Prepayments due to home sales are also called **turnover** or **mobility-related** prepayments. The sale of a mortgaged home will almost always result in the prepayment of the underlying mortgage. This is because most mortgage contracts have a "due-on-sale" clause embedded in them. Essentially, this clause stipulates that the lender can demand payment of the remaining balance of the loan when the house is sold.[3] Mortgages which contain no due-on-sale provision are called **assumable** and allow the new borrower (the person who is buying the home) to "assume" the payments on the existing mortgage. Government loans (FHA- and VA-insured mortgages) are assumable but it is now quite rare to find a conventional mortgage that is assumable.[4]

The importance of the "due-on-sale" clause becomes clear when we think about the situation where the home for sale carries a mortgage with a coupon that is significantly below prevailing mortgage rates. In this case, a potential buyer would clearly prefer to assume the existing mortgage (assuming that they can afford the down payment) rather than take out a new mortgage. The seller would also benefit in this situation since potential buyers would find the home more affordable. The only party that stands to lose

[1] Mortgages with a bi-weekly payment schedule also exist but are not very common.
[2] These costs will be discussed in detail later on.
[3] It should be noted that this is the lender's contractual right and not a requirement. In other words, the lender has the option of deciding not to call the loan due.
[4] FHA loans closed before December 14th, 1989 and VA loans closed before March 1st, 1988 are assumable by any buyer without restriction. For FHA/VA loans originated after these dates, the assumption process is a little more onerous. First, the buyer has to be approved by the relevant agency in the same manner that a new borrower is approved. Next, there are fees associated with the assumption: FHA allows lenders to charge a $500 assumption fee and a fee for the credit report. VA allows a $255 processing fee, a $45 closing fee and a funding fee of 0.5% of the loan balance.

from this situation is the originator who will not be able to collect origination fees on a new loan.

There is some interesting history behind assumable mortgages and the due-on-sale clause. The due-on-sale clause first came into the spotlight in the late 1970s/early 1980s, when a sustained increase in interest rates led originators to insert this clause in their mortgage contracts. Needless to say, consumers rebelled and after a protracted legal dispute the issue was resolved in favour of lenders by the Garn-St Germain Act of 1982. Basically, the Act provides for the federal pre-emption of any due-on-sale restrictions imposed by state law. Thus, it essentially codifies the enforceability of the "due-on-sale" clause.

Refinancing

In a refinancing, a homeowner replaces their current mortgage with a new one. Homeowners have various reasons for refinancing including obtaining a lower interest rate (**rate refinance**), shortening or lengthening the repayment period (**term refinance**), converting from an adjustable-rate to a fixed-rate mortgage or vice-versa, and extracting equity from the property (**cashout refinance**). In addition, borrowers with a poor credit history who typically pay higher mortgage rates can often qualify for a lower rate after making timely payments on their mortgage obligation over a prolonged period of time (**credit refinance** or **credit curing)**.

Curtailment

Sending in a monthly payment that is larger than the one required will result in the mortgage paying off before it is due. Curtailments therefore correspond to partial prepayments of the outstanding loan principal.[5]

Default

A mortgage default is defined as the failure to fulfill any of the terms of the mortgage contract including being late on monthly payments, failing to pay property taxes, failing to pay insurance premiums etc. In theory, even being one month overdue on the monthly payment would constitute a default but, in practice, mortgage default usually corresponds to persistent non-payment by the borrower.

For Fannie Mae, Freddie Mac and Ginnie Mae securities, loans that have been delinquent for three to four consecutive months are typically removed from the pool by the servicer. Since the agencies guarantee full and timely payment of principal and interest on their MBS, the investor sees this as a prepayment. For private-label securities, the convention is typically to **advance** monthly payments of principal and interest until the ultimate disposition of the mortgaged property. Any principal losses that are incurred in this process are of course passed onto bond holders depending upon their position in the cash flow waterfall.

[5] Since there often seems to be some confusion over this issue, it is worth pointing out that making a curtailment does not release the borrower from the obligation of making the full amount of their scheduled payments in the future. In other words, the amount of the curtailment cannot be used to reduce future monthly payments.

The above discussion shows that mortgage default typically results in the investor receiving early payment of their principal[6] and demonstrates why defaults are often called **involuntary prepayment**. In general, we will include defaults in the definition of prepayments even though we are being somewhat imprecise when we do so.

[6] It may not be the full principal for private-label securities.

III. THE IMPORTANCE OF PREPAYMENTS

If homeowners were not allowed to prepay their mortgages, the pricing and analysis of MBS securities would be a relatively simple exercise. The cash flows on an agency-guaranteed MBS would be the same in all interest-rate environments and would consist of the principal and interest payments made by the underlying mortgagors less a servicing and guarantee fee. In this situation, MBS investors would simply worry about the credit risk posed by the underlying corporations who were collecting and forwarding the mortgage payments (FNMA, FHLMC and GNMA). In other words, an MBS would be the same as a **non-callable** bond.

The complexity of MBS arises from the homeowner's right to prepay their mortgage at any time. Since this prepayment rate will depend upon interest rates, among other factors, the cash flows on the MBS will vary based on interest rates. Thus, it is imperative to be able to forecast prepayment rates in different interest rate environments in order to be able to accurately estimate the cash flows generated by the MBS investment in these environments.

In order to develop a more precise idea for how prepayment rates will depend upon mortgage rates, we need a more nuanced understanding of the homeowner's right to prepayment. The homeowner's right to prepay their mortgage through **voluntary** means (home sales, refinancing, curtailment) can be thought of as equivalent to the homeowner purchasing an option when they enter into a mortgage contract. More precisely, the voluntary prepayment option is like a **call option** with strike price equal to par (plus the transaction costs associated with refinancing). The voluntary prepayment option resembles a call option in that the borrower has the right to "call" back the balance of the loan at any time. One situation they would consider "exercising" this option is when the market value of their mortgage is greater than par. Since the market value of the mortgage is the present value of the remaining payments on the mortgage discounted at the prevailing mortgage rate, the lower the current mortgage rate is, the higher the market value of the mortgage. In down to earth terms, the lower the current mortgage rate is, the more the homeowner can save on their monthly payments by refinancing their mortgage. As a result of this equivalence between the right to prepayment and option contracts, market participants often use jargon borrowed from the options market to describe the incentives faced by the homeowner. Specifically, the homeowner's prepayment option is said to be **in-the-money** whenever market rates are lower than the rate on the existing mortgage, **at-the-money** when these rates are equal, and **out-of-the-money** otherwise.[7]

The dependence of home sales on interest rates is also fairly straightforward: a homeowner with a below-market mortgage rate has to face the additional frictional cost of increasing their monthly payments when they get a mortgage on the new house. Thus, higher mortgage rates tend to deter home sales.

It is worth pointing out here that the voluntary prepayment option has some aspects to it

[7] A more precise definition of "moneyness" would also consider the costs of refinancing a mortgage which are currently around 25bps.
[8] More precisely, the writer of the put option is the provider of the credit enhancement for the MBS. For investors in agency pools, for example, the MBS investor is only short the call option while the relevant Agency is the put option writer.

that you won't find in a call option. When the house is sold, the homeowner must prepay their mortgage whether it's economic or not. But, note that this exercise of the option in "out-of-the-money" situations may not be sub-optimal because the homeowner may be trying to maximize the return on the property (among other reasons) which may not be the same as trying to exercise the prepayment option optimally.

Since the homeowner also has the right to default (**involuntary prepayment**) on their mortgage, they also purchase a put option (in addition to the call option) when they enter into a mortgage contract. The right to default is like a put option because the borrower can turn over the house ("put the house") to the lender in exchange for foregoing future payments on the mortgage. The value of this put option is driven by the market value of the mortgage and the value of the house, which in turn is driven by trends in home prices.

To summarize the above discussion, in essence, the investor in an MBS has a short position in a call and put option and a long position in a non-callable bond with the same payment schedule as the MBS.[8] In equations:

$$\begin{aligned} \textit{Value of MBS} &= \textit{Value of Non-Callable Bond} \\ &- \textit{Voluntary Prepayment Option} \\ &- \textit{Involuntary Prepayment (Default) Option} \end{aligned}$$

The value of the MBS investment thus depends on the value of these options. The goal of prepayment modeling is to allow for precise quantification of the value of these options by building a predictive model for homeowner prepayment behavior.

IV. MEASURING PREPAYMENT RATES

How are prepayment rates calculated in practice? Since all of our data on homeowner prepayments comes from the MBS market, the prevailing conventions for calculating prepayment rates are strongly linked to the mechanics of the MBS market. Concretely, in a typical MBS structure, a group of residential mortgage loans is sold to a trust which in turn issues securities and makes monthly payments to investors out of the payments made by the homeowners. The monthly payments passed through to investors consist of scheduled principal, interest, and **unscheduled principal**. This unscheduled principal corresponds to homeowner prepayments.

To convert the dollar amount of the unscheduled principal to a prepayment rate, we first need a way to calculate the scheduled balance of the pool based on amortization of principal. This is straightforward because given a mortgage pool with a coupon, remaining term, and months elapsed since origination, we can compute the scheduled balance of the pool for each remaining month using a formula. This balance can then be compared to the actual balance of the pool and the difference between the two numbers corresponds to unscheduled payments of principal or prepayments. In equations:

Prepayment = Scheduled Principal Balance – Actual Principal Balance

This equation gives us the dollar amount of prepayments. To convert this dollar amount into the prepayment rate per dollar of principal over a month, we calculate the **Single Monthly Mortality (SMM)** rate. The SMM in any month for a pool of mortgages is given by the expression below. We can think of an SMM as calculating the fraction of loans outstanding at the beginning of the month that terminate because of prepayments:[9]

SMM = Prepayment/Scheduled Principal Balance

For example, consider a pool which has an outstanding balance of $1.1 million at the beginning of July and suppose we are expecting scheduled principal payments of $100,000 on the pool for the month. Now, suppose that at the end of the month we measure the total amount of principal payments received and we find the amount to be $110,000. Then:

Prepayment = Scheduled Principal Balance – Actual Principal Balance
= $1,000,000 - $990,000
= $10,000

July SMM = $10,000/$1,000,000
= 1%

The most common convention used to quote prepayment rates in the market is the **Constant Prepayment Rate (CPR)**. The CPR calculation is simply an annualized version of the SMM calculation, assuming that the SMM remains constant for twelve months. One can think of a CPR as calculating the fraction of loans outstanding at the

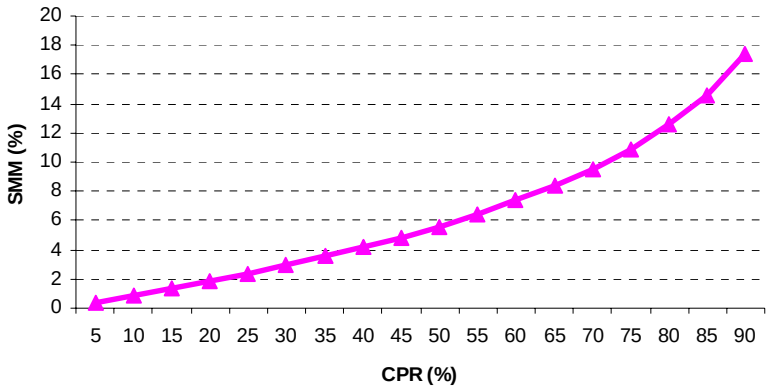
[9] The calculation implicitly assumes that we can think of each dollar of principal as corresponding to a single loan. Thus, all prepayments are whole prepayments on $1.00 unit loans within the pool.

beginning of the month that will terminate over the next year because of prepayments. SMM and CPR are related by the following expression:

$$CPR = (1 - (1 - SMM)^{12}) * 100$$

Figure 1 uses the above formula to plot the relationship between SMM and CPR for different prepayment speeds.

Figure 1: The Relationship between CPR and SMM



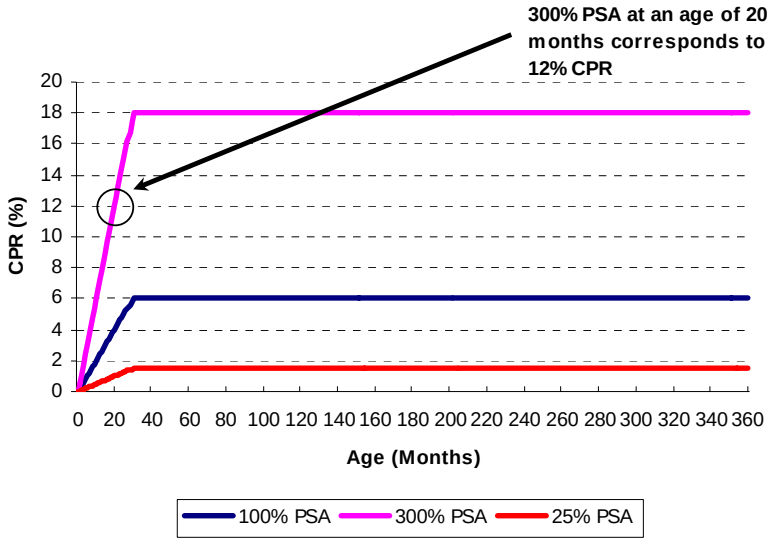
Source: Banc of America Securities

The third widely used convention for quoting prepayment speeds prevalent in the market is the **Public Securities Association (PSA) Curve**. Unlike CPR and SMM, the PSA convention calculates prepayment speeds by comparing them to a reference prepayment curve. This benchmark prepayment curve, also referred to as the 100% PSA curve, defines a vector of prepayments that is indexed to the age of the pool. The vector has speeds increasing linearly from 0% CPR at an age of 0 months to 6% CPR at an age of 30 months, and then remaining constant at 6% CPR as a function of age after that.[10] A speed of 300% PSA means that prepayment rates as a function of age would be three times the CPRs given by the 100% PSA curve. Similarly, speeds corresponding to the 25% PSA curve would be one fourth of the speeds given by the base curve. The 100%, 300% and 25% PSA curves are plotted in Figure 2.

Even though the convention for quoting speeds through SMM and CPR seems very different from the PSA convention, it is fairly easy to move from one measure to the other.[11] The only additional information required is the age of the pool. For example, a pool with an age of 20 months that is prepaying at 300% PSA has a prepay speed of 12% CPR (Figure 2), which in turn corresponds to 1.06% SMM.

[10] This ramp was originally developed using historical prepayment data dating from the early 80's to capture the seasoning effect commonly observed in mortgage securities.
[11] The conversion between monthly CPR and PSA is straightforward. Things become more complicated if we want to compare these metrics over longer periods of time (3 months, 6 months, etc).

Figure 2: The Relationship between CPR and PSA



Source: Banc of America Securities

Given that one can move from PSA to CPR and back, the question arises as to what purpose these different prepayment speed quoting conventions serve. One obvious difference is that the CPR quoting convention has no dependence on age, making it difficult to compare prepayment speeds on two MBS pools with different ages since speeds on more seasoned pools will generally be higher than on new ones.[12] On the other hand, the PSA convention gives us a direct way to compare speeds on pools with different ages. For example, take two pools with ages of 20 and 30 months respectively, both of which are prepaying at 12% CPR. Although both pools are prepaying at the same CPR, the PSA on the pool with an age of 20 months is 300% PSA whereas it is 200% PSA on the 30 month seasoned pool. Thus, one could conclude that the first pool is prepaying faster than the second one after controlling for seasoning. It is important to keep in mind that although PSA percentages provide a means of comparing prepayment speeds on pools, it is not advisable to assume that speeds will actually follow the PSA prepayment ramp in future months.

Although CPR is the preferred metric for quoting prepayment speeds, the PSA convention is still widely used for quoting the speed assumptions used to price Agency and Non-agency CMOs. This is primarily because the PSA curve incorporates a seasoning ramp similar to the ones observed on mortgage pools. Another commonly used prepayment curve in the Non-agency sector is the **PPC** or **Prospectus Prepay Curve**. Unlike the PSA curve, the PPC is not a standard curve and is deal specific. It is arrived at using collateral characteristics underlying the deal and is typically defined in the prospectus of the deal.

[12] We discuss the "seasoning effect" in MBS prepayments in detail in a later section.

V. A HIGH-LEVEL OVERVIEW OF HOMEOWNER PREPAYMENT BEHAVIOR

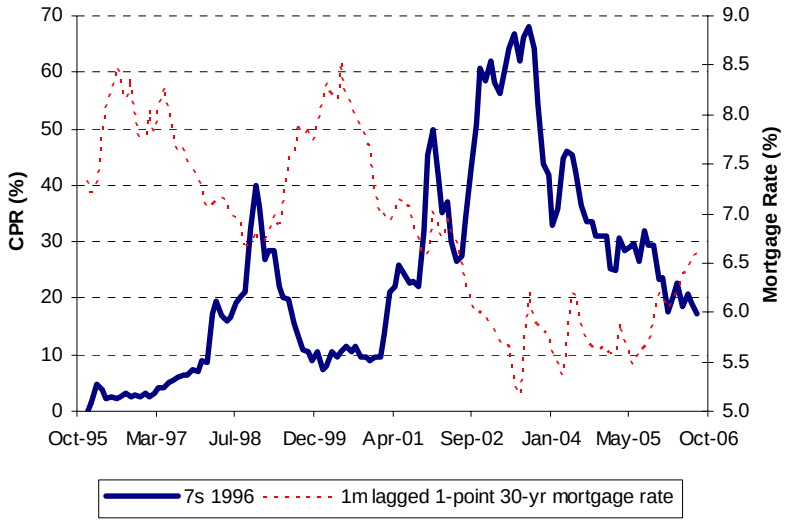
Now that we have some idea of what prepayments are, why they are important, and how they're measured, it is useful to get a broad sense for how they can vary as a function of interest rates. The prepayment speeds released on individual MBS pools can be very noisy because of the relatively small number of homeowners backing a pool so the convention is to look at prepayment rates on a collection of pools grouped together by pool coupon and the year that the loans were originated in. This grouping ensures that all borrowers in the pools we are tracking pay more or less the same mortgage rate and have held their mortgages for approximately the same amount of time. Figures 3 and 4 show prepayments on 7% pools (7s for short) originated in 1996 (average borrower mortgage rate = 7.59%) and 9% pools originated in 1991 (average borrower mortgage rate = 9.57%). We focus on describing the trends in Figure 3 first.

Let's start by getting a perspective for how high and low prepayment speeds can get. Prepayments speeds started out quite low on the 7s but ramped up to 7% by December 1997. The mortgage holders in the pool did not really have an opportunity to refinance over this period since mortgage rates ranged between 7.50% and 8.50% over the 1996-1997 time frame. This gradual ramp up of prepayment speeds over time is typical behavior for mortgage loans and is called the **seasoning ramp**.

As rates fell to around 6.70% in October 1998, we see a dramatic spike in prepayments speeds to 40% CPR in December 1998. At this juncture, mortgage rates had fallen to levels not seen since 1993 resulting in a massive increase in refinancing activity for most coupons. This type of explosion in refinancing activity is typically referred to as a **refinance wave** by market participants. Speeds gradually declined as mortgage rates begin to rise but never really fell below 9%-10% CPR over 2000 even though mortgage rates climbed all the way up to 8.50%.

The market saw a succession of refinance waves as rates fell almost continuously from a peak of 8.54% in May 2000 to a multi-decade low of 5.16% in June of 2003. It is interesting to note that at this point, speeds on the 7% pools reached "only" 66% CPR. We say "only" because even though prevailing mortgage rates were some 200+ bps lower than what they were paying, some homeowners in these pools did not prepay. The takeaway is that even at very high levels of rate incentive, prepayment rates on mortgage pools do not reach 100% CPR.

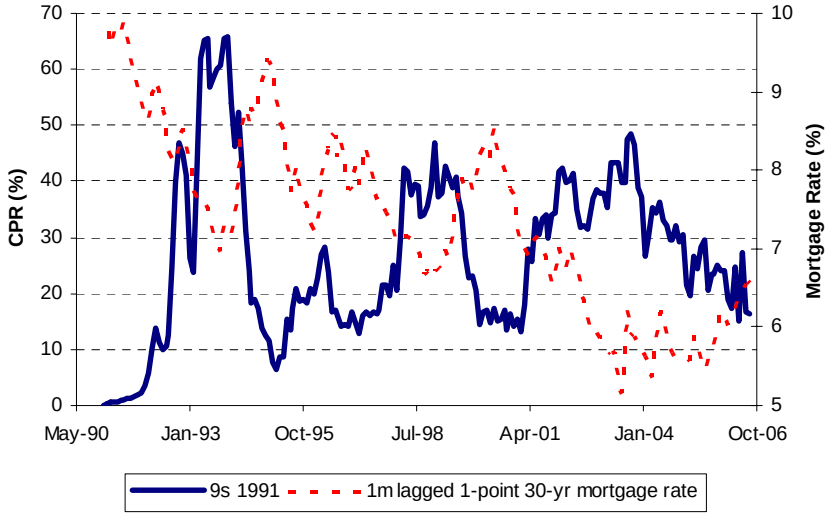
Figure 3: Prepayment Rates on 7s of 1996



Source: Banc of America Securities

Figure 4 contains many of the same themes as the previous figure but the key point here is to highlight a phenomenon which is not really visible in Figure 3: the **burnout** of mortgage pools. As the terminology suggests, after an MBS pool has been through a refinancing episode, exposure to the same or greater refinancing incentives does not lead to the same refinancing response. For example, speeds reached 61% CPR on the 9s in November 1993 corresponding to a 30-year mortgage rate of 6.97%. But, when rates reached 6.70% in September-October 1998, prepayment rates on the 9s only peaked at 50% CPR.

Figure 4: Prepayment Rates on 9s of 1991



Source: Banc of America Securities

While our discussion above helps build an overall picture for the total variation we can expect to see in prepayment speeds and some general patterns that are typical of MBS prepayment rates, it doesn't really give us a feeling for what causes these patterns and variations, or how the individual components of prepayment (home sales, refinancing, curtailments, default) contribute to this picture. The goal of the next few sections is to delve into the details of each of the different components of prepayments and fill out some of the missing elements of the picture.

VI. THE COMPONENTS OF PREPAYMENT: HOME SALES

The first component of prepayments we will analyze in detail is home sales (or **turnover**). Since home sales result from people moving out of their homes (the academic term for this is **residential mobility**), understanding what makes households move is very useful as a prelude to studying turnover.

Why do People Move?

The U.S. Census Bureau periodically tabulates mobility rates and the reasons why households move as part of their population studies. Even though the Bureau's survey encompasses both homeowners and renters, the results (see Figure 5) do give us a sense for some of the motivating factors behind a move. For example, the figure shows that the desire to own a "new/better house/apartment" is the dominant reason cited in the decision to move. If we ignore the "Wanted to own home/not rent" reason which is not relevant for homeowners, the next most important determinant of mobility is a new job or a job-related transfer.

In general, this data is consistent with academic theory which views mobility as a mechanism that households use to adjust their consumption of housing services. Some of the reasons for this adjustment in consumption can be a change in the household's financial circumstances or an increase in the size of the family.

However, it should be kept in mind that borrowers cannot always adjust their housing consumption "instantaneously" because of the transaction costs associated with moving. These costs include both search costs (the hassle involved in trying to find a suitable new dwelling) and broker costs (fees paid to the broker for selling the home). Furthermore, interest rates will also play a role in the borrower's ability to move particularly if the market rate for a new mortgage is higher than the rate on the borrower's current mortgage. Thus, a below-market mortgage rate restricts the mobility of the homeowner – this is the so-called **lock-in effect**.

Figure 5: Reasons for Moving by Type of Move: 2002 to 2003

Reason	All movers
Percent	**100.0**
Family-related Reasons	**26.3**
Change in marital status	6.7
To establish own household	7.0
Other family reasons	12.6
Work-related reasons	**15.6**
New job/job transfer	8.8
To look for work/lost job	1.9
Closer to work/easier commute	3.2
Retired	0.3
Other job related reason	1.4
Housing-related reasons	**51.3**
Wanted to own home/not rent	10.2
New/better house/apartment	19.8
Better neighborhood/less crime	3.8
Cheaper housing	6.5
Other housing	11.0
Other reasons	**6.8**
Attend/leave college	2.5
Change of climate	0.4
Health reasons	1.4
Other reason	2.5

Source: U.S. Census Bureau

Explanatory Factors for Modeling Mobility

The above discussion gives us some sense of why people move and this in turn gives us a potential list of viable candidates for modeling turnover-related prepayments. Unfortunately, as commented earlier, the data currently available on MBS do not include demographic variables such as the age of the borrower or the size of their family. Thus, in many cases, we have to use proxy measures to attempt to capture some of the variables that effect mobility.

Loan Characteristics

Some of the characteristics of the loan can provide important information about the borrower's propensity to move. The borrower's mortgage rate will be important since, as we have already pointed out, borrowers with below-market mortgages face a disincentive to move. The number of points paid at origination will also be an important factor since borrowers who will pay more points probably intend to stay longer in their homes.

Housing Market and Economic Conditions

Labor market conditions are important in determining mobility but are rarely used in prepayment models since these conditions are hard to forecast over the entire term of the mortgage. Home prices are used in prepayment models although one could argue that they are equally challenging to forecast. Basically, home prices affect mobility by determining the value of the house and the amount of equity the borrower has. Increasing home prices result in increased home equity which can be used as a source for the down

payment on the larger home that a household needs. Also, rapid increases in home prices can also encourage turnover through speculative activity ("property flipping"). On the other hand, a decrease in home price erodes equity and constrains the ability of the household to trade up. It may also result in an inability to sell the house.

Time and Seasonal Indicators

The age of the head of the household is an important index for one of the primary drivers of mobility: housing dissatisfaction. Age is correlated with wealth and the size of the family, hence the link between age and the desire to own a "new/better house." Given the absence of demographic variables in our MBS data set, we use the age of the mortgage loan as a proxy for the length of time-in-residence. Of course, the age of the mortgage is also correlated with the age of the borrower. Finally, the age of the mortgage is also linked to the household's willingness to move. As the mortgage "seasons", the typical household will be more receptive to a move as they recoup the costs they incurred by moving into their current house. Seasonal adjustments are also important since moves are more likely in certain times of the year compared to others.

Patterns in Mobility-based Prepayments

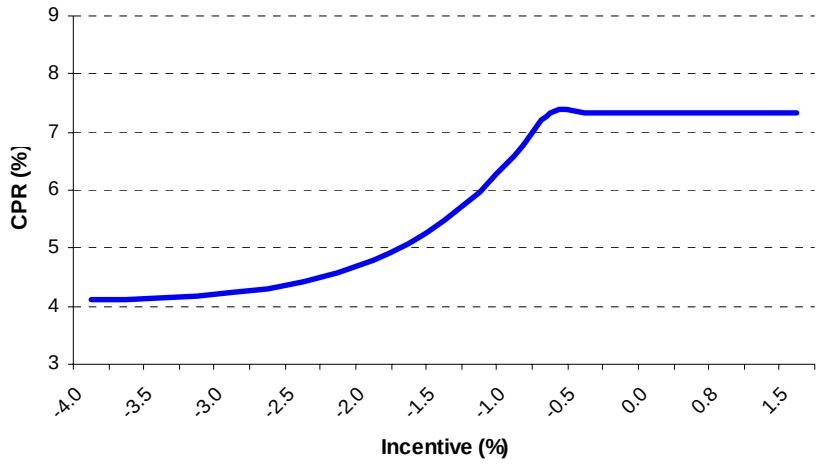
The previous paragraphs provided us with a list of explanatory variables that are linked to the likelihood of mobility. The goal now is to explore the variation between mobility rates and these variables. All of our analysis is based on prepayment rates observed on 30-year Fannie Mae and Freddie Mac pools.

The Lock-In Effect

The data presented in Figure 6 illustrates turnover-related prepayments on 30-year MBS pools as a function of the MBS pool's "incentive." The incentive is calculated here as the difference between the pool's weighted-average coupon (WAC) and prevailing mortgage rates – more negative values of this metric correspond to situations where prevailing rates are higher than the borrower's rate. The relationship between turnover rates and incentive depicted in the figure seems intuitively reasonable. First, since the fundamental drivers of mobility are housing dissatisfaction and job changes, interest rates don't really affect a borrower's ability to move when the pool is "in-the-money." The figure shows that the long-run average of the mobility rate of the 30-year mortgage holder stabilizes between 7%-8% as the incentive gets more positive.

On the other hand, as prevailing mortgage rates rise above the pool's WAC, the homeowner finds it increasingly difficult to move. Mobility rates steadily decrease as the amount of "disincentive" increases up to a certain juncture beyond which further increases in mortgage rates don't have an effect on borrower moves. The reason for this is probably that a certain amount of "forced" job-related moves occur regardless of interest rates. Note that even if mortgage rates are very high, the borrower does have the option of moving to rental housing in this situation.

Figure 6: The Lock-in Effect



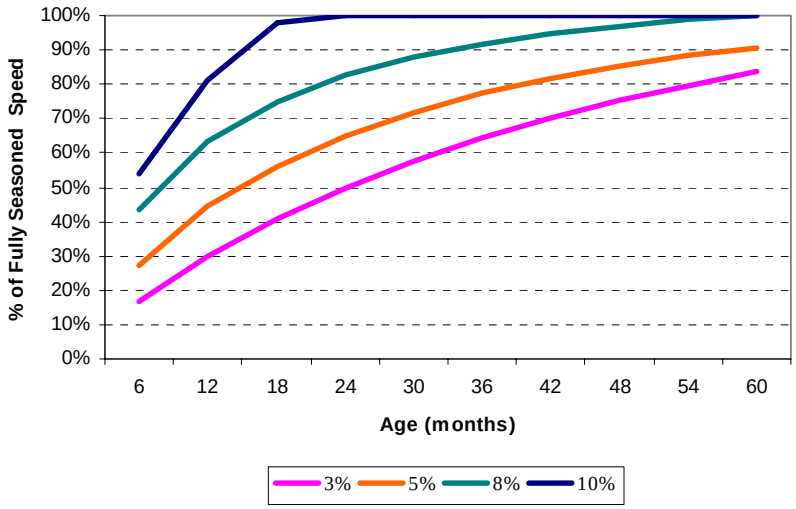
Source: Banc of America Securities

The Seasoning Ramp

The seasoning ramp for MBS captures the fact that most households get progressively more "dissatisfied" with their housing as their income trends up and the size of their family increases. In addition, the sunk costs associated with the initial move become less of a factor with time.

Figure 7 illustrates a number of seasoning ramps for 30-year mortgage pools indexed by the average annual increase in home prices experienced by the borrower over the observation period. Notice the distinct dependence of the steepness and length of the seasoning ramp on the amount of equity the homeowner has built up. Homeowners experiencing an average annual rate of appreciation of 8% are "fully seasoned" (at their maximum mobility rate) in a period of 5 to 6 years. On the other hand, an annual rate of 10% can lead to the mortgage pools being fully seasoned in two years. All of this is very consistent with our prior discussion of the impact that home prices should have on mobility-related prepayments.

Figure 7: The Seasoning Ramp for Housing Turnover



Source: Banc of America Securities

Seasonal Factors

Home sales exhibit a pronounced seasonal pattern with the seasonal highs in sales activity occurring in the summer and the lows in winter. The driving factors behind these seasonal patterns include the school year calendar and the weather. Figure 8 summarizes the seasonal factors calibrated from a study of turnover-related prepayments. It indicates that the prime months to move occur in the middle of summer (May through August) with activity gradually tapering down into the winter months. January and February are the worst months to move.

Figure 8: Seasonal Factors for Housing Turnover

Month	Seasonal Adjustment	Pct. Change from Previous Month
Jan	0.70	-19%
Feb	0.72	3%
Mar	0.97	35%
Apr	0.97	0%
May	1.16	19%
Jun	1.28	11%
Jul	1.22	-5%
Aug	1.21	0%
Sep	1.01	-17%
Oct	1.00	-1%
Nov	0.90	-10%
Dec	0.86	-4%

Source: Banc of America Securities

VII. THE COMPONENTS OF PREPAYMENT: REFINANCING

Refinacings constitute the most important component of prepayments and are the most challenging to predict because refinancing rates can go from 0% to nearly 70%-80% depending upon where mortgage rates are.

Why do People Refinance?

Homeowners have various reasons for refinancing including obtaining a lower interest rate, changing other terms of their mortgage (converting from an adjustable-rate to a fixed-rate mortgage or shortening/lengthening the repayment period), and liquefying equity. In addition, borrowers with poor credit who pay higher rates (since such borrowers have a higher propensity to default) can often qualify for a lower rate after making their monthly payments in a timely manner over a prolonged period of time. This phenomenon is known as **credit curing**. Credit curing is still on the rare side for borrowers in FNMA and FHLMC pools since most of these homeowners have pristine credit histories.

A recent study by the Fed[13] surveyed homeowner refinancing activity over 2001 and early 2002 and provides a breakdown of the relative importance of these different reasons for refinancing. The overwhelming motivating factor behind refinancing is obtaining a lower rate and thus reducing the homeowner's monthly debt service burden – 96% of all homeowners who refinanced over the survey period obtained a lower rate.

A small number (approximately 10%) of refinancing homeowners shifted from fixed-rate to adjustable-rate mortgages (ARMs) when they refinanced. Since ARMs have lower rates in upward sloping yield curve environment, they may be attractive to refinancers who plan to move in the near future or who expect future interest rates to remain stable or decline further.

Refinancers can also lower their monthly payment by lengthening the term to maturity on their debt. After refinancing, 74% of homeowners had mortgages with a longer maturity because they chose 30-year mortgages and extended the term of their mortgage by about 6 years on average. 17% of homeowners chose 15-year mortgages and shortened their maturity by an average of 7.5 years, while the remainder kept the maturity roughly the same.

A significant number (45%) of homeowners who refinanced over the survey period used the opportunity to extract some of their home equity. This cash is used for various purposes including debt repayment, home improvements and consumer expenditures. Only 27% of homeowners who liquefied equity had a lower payment as a result of taking on more debt.

[13] Canner, Glenn B., K. Dynan and W. Passmore. 2002. "Mortgage Refinancing in 2001 and Early 2002." *Federal Reserve Bulletin*, December 2002.

Explanatory Factors for Modeling Refinancing

Refinancing Incentive and Lag

The **refinancing incentive** for a given loan (or pool of loans) can be defined as the difference between the mortgage rate of the loan (or WAC of the pool) and prevailing mortgage rates. Prevailing mortgage rates are calculated using the weekly Freddie Mac Survey rate (often referred to as PMMS – Primary Mortgage Market Survey Rate), a widely used reference for the industry which applies to conventional conforming loans with LTVs of 80% or less.

The refinancing incentive needs to be adjusted for the costs associated with refinancing a loan, loan size (larger loans have a greater incentive to prepay) and servicer effects (certain servicers are more efficient in refinancing their borrowers and soliciting refinances from their servicing portfolios). The incentive also needs to be lagged: the current month's refinancing driven prepayment rates typically reflect rates from 4 weeks to 6 weeks ago since it takes about 4 to 6 weeks to process a refinancing application.

Growth in Home Equity

As the Fed survey pointed out, several cash-out refinancers accept a higher monthly payment on their mortgage in order to access the equity in their homes.[14] To model these out-of-the-money refinances, we need to calculate the average amount of equity accumulated by homeowners.

Exposure to Refinancing Opportunities

The phenomenon of **burnout** results from "borrower heterogeneity". The phrase "borrower heterogeneity" is shorthand for saying that mortgagors can exhibit significant diversity in their prepayment behavior. Most academic and Wall Street research indicates that these differences stem from one or more of the following factors:[15]

- Differences in the explicit transaction costs paid by mortgagors. For example, regional differences in the mortgage market may mean that two borrowers refinancing the same mortgage may face different levels of transaction costs.
- Differences in "non-observable" transaction costs such as the search costs and credit barriers faced by different borrowers.
- Differences in borrower level collateral and liquidity characteristics such as the amount of home equity available or availability of cash to cover refinancing costs.
- Differences in the personal attributes of the mortgagors such as knowledge, temperament, decisiveness or risk preference.
- Differences in the expected holding period for the house.

Many of these differences are unobservable at the pool level, but nevertheless manifest themselves through the phenomenon of burnout in mortgage pools. To capture this heterogeneity, we partition the pool of borrowers into three groups (also referred to as

[14] To the extent these refinancers are using this equity for debt consolidation purposes, the effective coupon on their overall monthly debt burden may be lower.

[15] A good review of the academic literature on this topic can be found in "Controlling for Burnout in Estimating Mortgage Prepayment Models", Arden Hall, *Journal of Housing Economics*, Volume 9, Issue 4, 2000.

"classes" or "populations") – "slow", "medium" and "fast" – based on how efficiently they refinance their mortgages. We will explain later why this simple idea captures the dynamics of burnout when we discuss patterns of refinancing behavior.

Past History of Mortgage Rates

Empirical data shows that homeowner prepayment rates are sensitive to the past history of mortgage rates (see Figures 4 and 5). Specifically, homeowner refinancing rates appear to ignite when mortgage rates reach multi-year lows. This surge of refinancing activity results in a **refinance wave** ("refi wave" for short). This effect has been variously described as the **Media Effect**, the **Publicity Effect**, and the **New Rate Low Effect**. The terminology used to describe this phenomenon provides another likely cause for this effect: multi-year lows in mortgage rates typically spark extensive media coverage and proactive solicitation of refinancings by servicers who wish to protect their servicing portfolios thus resulting in lower transaction costs for refinancing.

To model the publicity effect, we need to develop an index that provides a proxy for the strength of this effect. There are a couple of potential choices. For any given month (or week), one could calculate the number of months (or weeks) since rates have been this low. Another option would be to calculate the "in-the-moneyness" of the current mortgage universe. In general, the greater the number (or dollar amount) of refinanceable mortgages, the higher the value of the publicity effect.

Seasonals

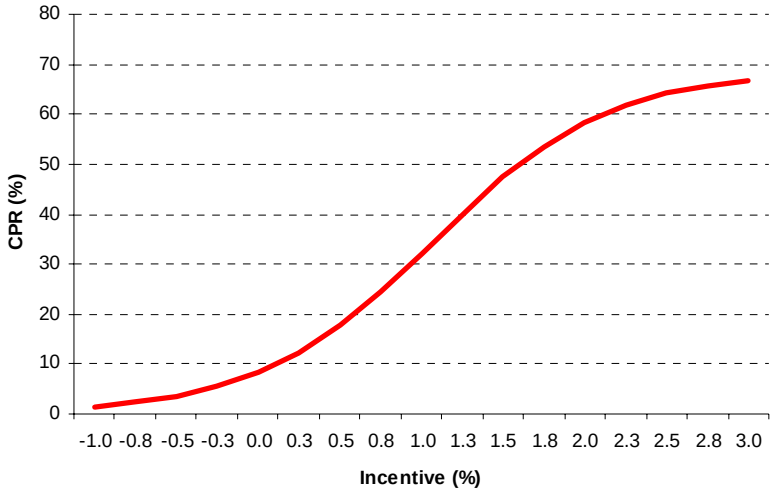
Since homeowners can prepay on any day of the month, the number of business days in the month will affect the total dollar volume of prepayments that is collected by servicers. All else being equal, months that consistently have a fewer number of business days (February) will correspond to lower prepayment rates. The holiday calendar also has an effect refinancing rates since most homeowners (and originators) will not be motivated to refinance over the last few weeks of December and the first week of January.

Patterns in Refinancing-related Prepayments

Refinancing S-Curve

It is useful to begin our analysis of refinancing by looking at the simplest and most important aspect of the empirical data: the refinancing rate as a function of incentive. The results are presented in Figure 9. The distinctive shape of the refinancing response function is similar to that of an "S", hence the name "S-curve." Notice that even when the mortgage is at- or out-of-the-money, the refinancing response is still not zero. This can be attributed to the prevalence of cash-out refinancing through which homeowners frequently raise their mortgage rate while using their mortgage as a debt consolidation vehicle. As the incentive increases, we notice an increase in refinancing activity with the slope of the "S-curve" steepest near the at-the-money zone and then gradually flattening out as incentive increases. The intuition is that at some threshold level, a small increase in incentive takes a number of potential refinancers off the fence. As the overall incentive increases, the marginal increase in refinancing activity because of an increase in incentive starts to diminish.

Figure 9: The Refinancing S-Curve



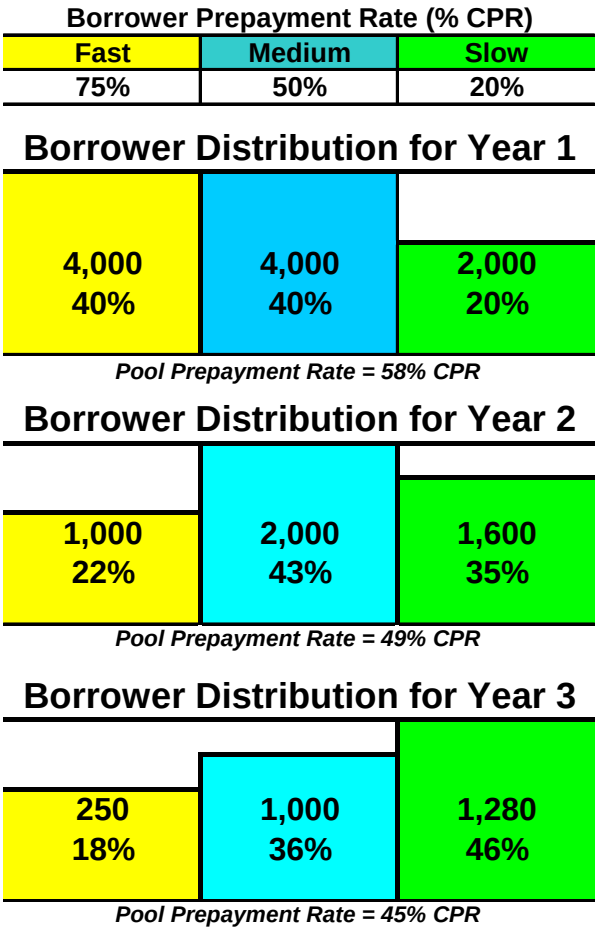
Source: Banc of America Securities

Burnout

The presence of borrower heterogeneity means that the refinancing propensities of a pool of mortgage borrowers range from "inefficient" to "ruthless." Now, in the presence of refinancing incentives, the more "ruthless" refinancers will leave the pool earliest and leave behind a collection of relatively less efficient refinancers. Over time, this will cause aggregate prepayment speeds on the pool to gradually decay. Also, if rates rise and then fall again to the initial level that stimulated refinancings, the same pool will refinance at a lower rate than before since it has a smaller proportion of "ruthless" refinancers.

A simple model that captures these dynamics is presented in Figure 10. We assume mortgagors fall into three distinct groups when classified by their refinancing propensity: "Slow", "Medium", and "Fast". The observed refinancing rate for the pool will be the average of the refinancing rates for the different borrowers, weighted by the proportion of the pool in that particular category for that particular month. Note that the differing refinancing rates of the three classes dramatically change the composition of the pool over a period of two years in our example. In year one, "Slow" borrowers only make up 20% of the pool, but by year three they have more than doubled their representation of 46%. Also, for the same incentive, the pool prepayment rate has fallen from 58% CPR to 45% CPR because of the relatively quick exodus of "fast" refinancers.

Figure 10: Modeling the Burnout Effect

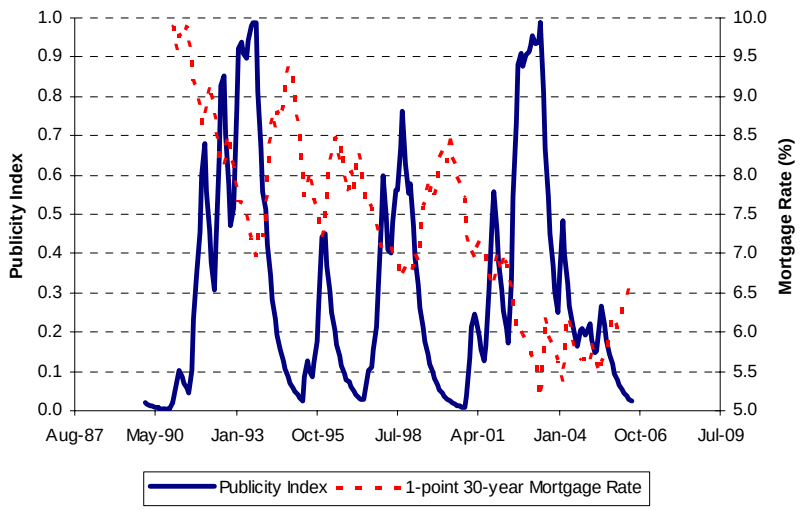


Source: Banc of America Securities

Publicity Effect

We start by creating an index that measures the overall refinanceability of the mortgage universe. The "history" of this index is presented in Figure 11 below. Basically, a Publicity Effect of 1.0 corresponds to the "Mother of all Refinance Waves" (June 2003), whereas a Publicity Effect of 0 corresponds to a situation where almost all existing mortgages are not refinanceable.

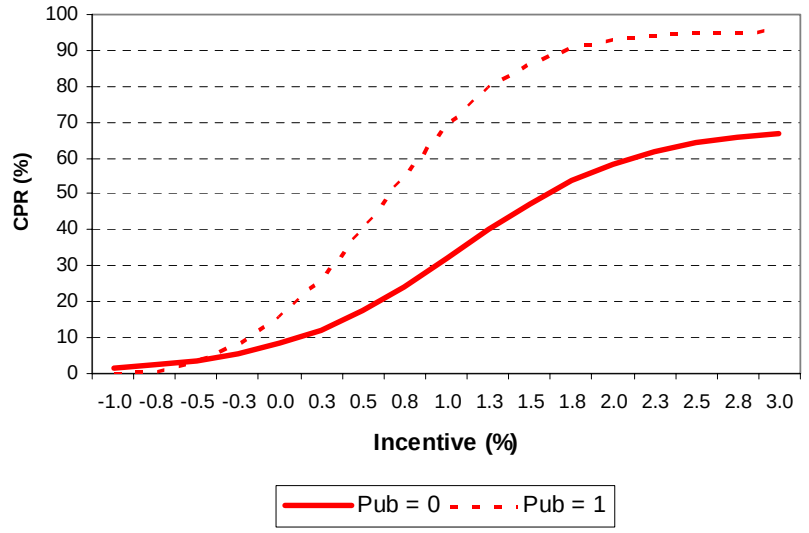
Figure 11: The Publicity Effect



Source: Banc of America Securities

In practice, we can implement a Publicity Effect in the model by defining an "efficient" refinancing S-curve (corresponding to a Publicity Effect of 1.0) and a "base" refinancing S-curve (corresponding to a Publicity Effect of 0). Figure 12 illustrates what these S-curves would look like in practice. We can then use the value of the Publicity Effect to compute a blended average of the "base" curve and the "efficient" curve.

Figure 12: The Refinance S-Curve in Different "Publicity" Environments



Source: Banc of America Securities

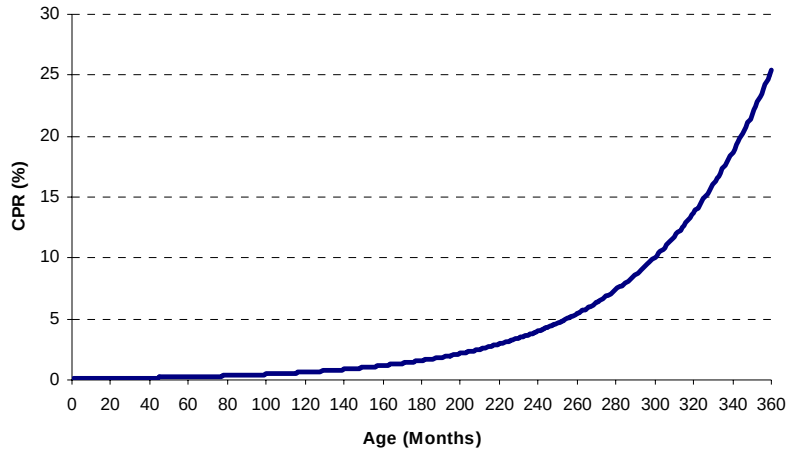
VIII. THE COMPONENTS OF PREPAYMENT: CURTAILMENT

On the face of it, curtailment appears to be a sub-optimal strategy for homeowners. After all, if a mortgage is in-the-money, the homeowner should prepay the outstanding balance of the mortgage in full as opposed to in part. The weakness in this argument lies in the fact that the transaction and hassle costs associated with refinancing a mortgage can be significant. This is particularly true in the situation where the mortgage carries a penalty for refinancing. If a borrower cannot refinance because of the costs involved, curtailment is the optimal strategy. Alternatively, some households may simply want to reduce the amount of their indebtedness by paying off as much of their mortgage debt as they can.

Patterns in Curtailment-related Prepayments

The empirical data on curtailment rates are consistent with the discussion above. In general, the rates are pretty low but can ramp up sharply towards the end of the life of the mortgage presumably because homeowners are now older and wish to be debt-free. Other studies have also shown that curtailment rates on mortgages that carry a prepayment penalty can be fairly high. Figure 13 presents a simple curve that fits curtailment data on 30-year agency pools quite accurately. The figure shows that curtailment rates gradually increase from 0 to 4% CPR over the first 20 years of the mortgage and then can jump as high as 25% CPR in the last few years of the mortgage's maturity.

Figure 13: Curtailment on Conventional 30-year Mortgages



Source: Banc of America Securities

IX. THE COMPONENTS OF PREPAYMENT: DEFAULT

The homeowner's right to default can be viewed as them owning a put option on the house. In down to earth terms, a necessary condition for the borrower to default is if the value of the house is less than the market value of the mortgage.[16] The condition is not a sufficient condition for default because the borrower has to weigh the costs associated with moving, the cost of a damaged credit record, and the expected cost of deficiency judgments.[17] In addition to negative equity, borrowers typically have to be subject to some **trigger event** to default – a shock to their income resulting from sustained unemployment, a divorce, an unexpected increase in health-related costs or some other form of liability.

Patterns in Default-related Prepayments

Default rates on mortgages show a distinct dependence on the age of the mortgage. The general pattern can be described as follows. Default rates start out low since lenders will not underwrite borrowers who they suspect will default immediately. Also, since mortgages with LTVs of 100% or greater are still fairly rare in the U.S., most borrowers typically have positive equity at origination. We start to see default rates ramp up gradually in the first two or three years after origination since it is over this period that borrowers are most vulnerable to losing all their equity if home values decline. After this, default rates start tapering off five or more years after origination since increases in home prices and an increasing amortization effect decreases the likelihood of negative equity.

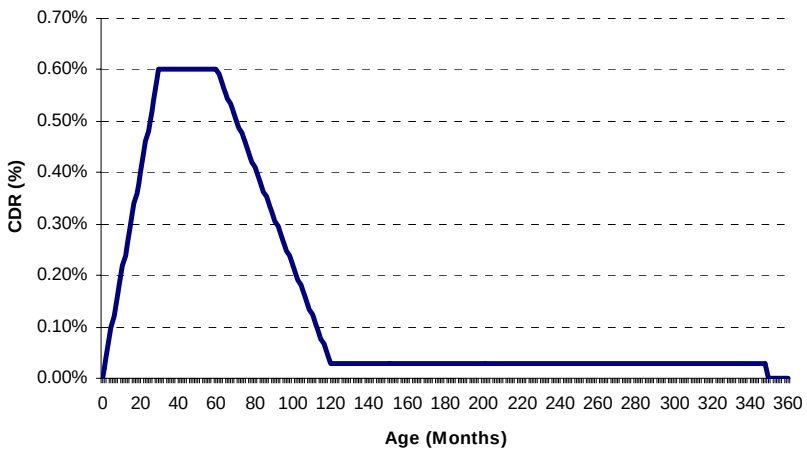
The SDA Model for Defaults

The **SDA** (**Standard Default Assumption**) model is a benchmark curve for default analysis developed by the Bond Market Association. The curve is presented in Figure 14 and is given by the following prescription:

- Beginning with a CPR of 0.02%, default rates increase by 0.02% CPR per month until month 30, when the peak value of 0.60% is reached;
- Defaults remain at the value for the next 30 months;
- Starting in month 61, defaults decrease by 0.0095% per month until month 120, when the tail value of 0.03% is reached. Defaults remain constant at this level for the remaining life of the security.
- By convention, the last 12 default rates are set to zero, assuming it takes 12 months to liquidate a property.

[16] The market value of the mortgage is an important component of the homeowner's decision to default. A discount mortgage is more valuable to the homeowner than a premium because in the former case they could potentially be forced to increase their mortgage rate when they moved.
[17] In a deficiency judgment, creditors are allowed to collect an amount equal to the lender's foreclosure losses against the borrower's other assets. These judgments are rarely pursued but may be used as leverage against borrowers. Most states allow deficiency judgments but they are prohibited in 9 states (including Calfornia).

Figure 14: The SDA Curve



Source: Banc of America Securities

Strengths and Weaknesses of the SDA Model

The shape of the SDA curve more or less captures the age dependent nature of default rates described above. It works reasonably well because age is strongly correlated with equity growth, which is one of the primary determinants of the decision to default. The weaknesses of the model are its lack of dependence on other macroeconomic (strength of the labor market) and microeconomic (the borrower's current LTV, credit score and debt-to-income ratios) variables that are likely to have a strong impact on default rates.

X. PREPAYMENT MODELS AND MODEL BUILDING

At a very high level of abstraction, a prepayment model simply tries to successfully predict the all the different patterns of prepayment behavior we have seen in our discussion above. It is essentially an "economic" model that tries to predict the behavior of homeowners by regressing prepayment data on thousands of mortgage pools against factors that influence prepayment speeds. The common collateral level characteristics that are used as inputs to the prepayment model are presented in Figure 15. A road map for the typical model building process is presented in Figure 16.

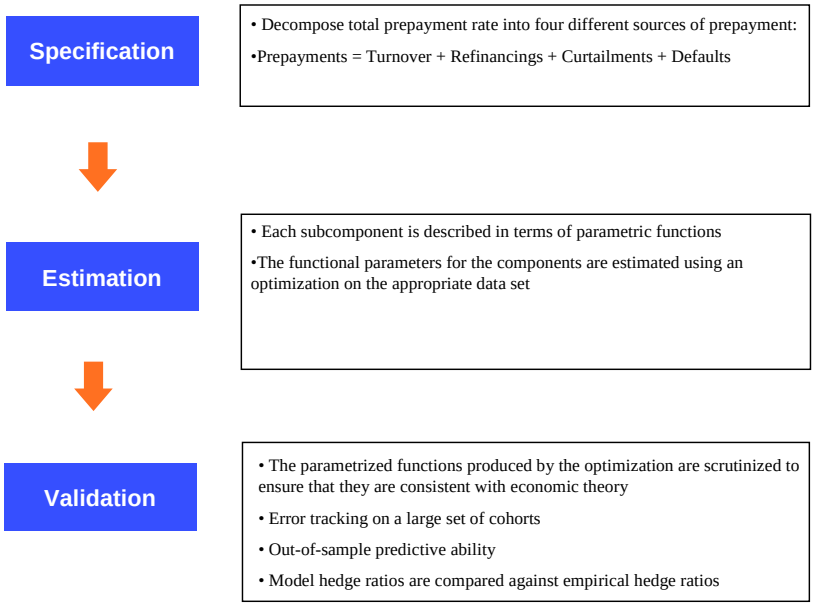
Figure 15: Pool-level Collateral Characteristics Used in Prepayment Model

Pool-level Indicative	Description
WAC	Weighted-average coupon
WALA	Weighted-average loan age
WARM/WAM	Weighted-average remaining maturity
WAOLT	Weighted-average original loan term
ACLS	Average current loan size
AOLS	Average original loan size
Geographic Distribution	The percent of the total pool balance represented by loans in each state
Seller	Entity that sells the mortgage loan to the MBS issuer
Factor	Fraction of original principal outstanding
WAOLTV	Weighted-average original LTV
WAOCS	Weighted-average original credit score
Loan Purpose	Purchase, Refinance
Property type	Single-Family, 2-4 Units, etc
Occupancy type	Owner-occupied, Investor, Vacation
Servicer	Entity that services the mortgage loans
WAMTAM	Weighted Average Months to Amortize
Product Type	ARM/Fixed/Hybrid, IO term, Index, margin, etc

The weights for each pool attribute calculation correspond to the outstanding balance of each loan in the pool relative to the total balance

Source: Banc of America Securities

Figure 16. Summary of Prepayment Modeling Framework



Source: Banc of America Securities

XI. THE USES AND LIMITATIONS OF PREPAYMENT MODELS

The oft-quoted aphorism "All models are wrong, but some are useful"[18] is definitely applicable to the case of prepayment models. Hopefully, at this point the reader is fairly convinced that a good prepayment model is a foundational block for MBS analysis. In addition to allowing us to estimate the risk/return characteristics of specific MBSs, the model allows us to compare these characteristics for MBSs with differing collateral characteristics and structures in a consistent and coherent way. The ability to make these types of comparisons is, of course, the heart of "relative value" analysis. The most useful prepayment models are dynamic: The dynamic nature of MBS prepayments is not well-approximated by constant CPR and PSA assumptions and analyses that rely on these assumptions probably understate the risk of the MBS.

Of course, since life is rarely perfect, there are some complications associated with using prepayment models. The drawbacks associated with relying on a model are generally categorized under **model risk** – The risk that the model you are using is "wrong." There are many ways to be wrong. The model may not be correctly "specified" (For example, trying to model the refinancing response of the homeowner versus their refinancing incentive using a linear function when, as Figure 9 shows, the appropriate function is S-shaped). Next, the model may not be correctly estimated (For example, it was estimated using bad data), and it may not even be implemented correctly (There is an error in the software program that implements the model). Even assuming we can traverse the above hurdles, the very strategy used to "fit" the model – regressing prepayment rates versus a collection of explanatory variables based on historical data gives rise to problems because the past is rarely a good predictor of the future. Stated differently, by construction, a prepayment model is "backward looking" but the prepayment behavior of the homeowner is unlikely to remain the same in the future. We can more or less be certain that homeowners will become more efficient in exercising their prepayment options in the future as the cost structure of the mortgage industry continues to be driven lower by competition and the pervasive use of technology to streamline all parts of the mortgage origination process. The problem is that it is very difficult to estimate how rapidly and by how much.

Without going into the details, we will conclude with an outline of some popular approaches to correct for the backward looking nature of prepayment models. First, if we assume that the market prices of securities accurately reflect future prepayment expectations, we can calibrate the parameters of our model to these prices. This gives us a **market-implied** prepayment model. Alternatively, we can use an adaptive model that updates its parameters every month based on the difference between actual and projected prepayment rates. Finally, we can compute the **prepayment duration** of a MBS by looking at how the prices of the security are impacted by a change in the model. Comparing the prepayment duration of the MBS then gives us a feeling for how vulnerable our risk/return analysis is to an inaccurate prepayment forecast.

[18] Attributed to the industrial statistician George Box.

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