The Competing Risks Framework for Mortgages: Modeling the Interaction of Prepayment and Default

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This article discusses how prepayment and default constitute competing risks in mortgage lending, provides examples of the importance of using a combined approach when evaluating the risk of whole loans and MBS, and concludes with practical implications of using the competing risks framework.

Though it may seem apt, the phrase “competing risks” in the title of this article does not refer to the annual budget battle between various risk management functions within large financial institutions. Rather, it is a framework for modeling the impact of separate causes for attrition. In the mortgage world, these are the separate, but interdependent, risks of prepayment and default. For prime mortgages (whole loans) and for mortgage-backed securities (MBS), prepayment risk has long dominated the issue of credit risk. Historically, in the secondary market, the three government-sponsored enterprises (GSEs) guaranteed the credit risk of most conforming mortgage loans, which represented the bulk of the primary market.

However, a recent issue of Inside Mortgage Finance (IMF, June 10, 2005) noted the following fact: “During the first three months of the year, non-prime lenders churned out an estimated $184 billion in new loans. Putting that into perspective, more than one out of every four loans—or 28.5%—of all new mortgages made during the first quarter of the year went to borrowers in the subprime and Alt A categories.” Moreover, SMR Research Corporation estimates over $700 billion in junior liens outstanding at the end of 2004 (Home Equity Loans: 2005 Outlook). Therefore, loans with greater credit risk represent a significant and increasing portion of the primary mortgage market.

A large number of these loans, and the associated credit risk, are held on the balance sheets of large financial institutions. The IMF estimated that the 50 largest financial services holding companies held a combined $1.01 trillion in whole loans during that same first quarter of 2005. Moreover, according to Inside MBS & ABS (July 17, 2005), a weekly newsletter published by the IMF, Fannie Mae and Freddie Mac bought $212 billion in non-conforming MBS during 2004, assuming much of the credit risk for the underlying mortgages.1 Thus, the increasing credit risk in the system is held by a large number of institutions, and even the GSEs now must learn to assess the greater credit risk from non-conforming products.

These recent developments increase the importance of default risk vis-à-vis prepayment risk for mortgage lenders, whether they are portfolio lenders or buyers of...
MBS. However, the presence of prepayment risk limits the applicability of traditional approaches to default modeling. The competing risks framework for modeling prepayment and default confers important advantages relative to these traditional approaches, particularly in the context of valuation, risk management, and capital allocation.

The Need for Hazard Models

As with other types of consumer assets, it is important to address the timing of the default event, and to account for static predictive variables. But mortgages are unique in offering the borrower an important and valuable option to prepay the loan early. Other consumer loans are prepayable, but only mortgages offer a significant financial reward for careful use of the option. This poses a particular challenge for default modelers. Consumers frequently use the prepayment option when it is to their advantage. When interest rates reached 30-year lows in 2003, the monthly prepayment rate for prime mortgages reached nearly 7%. The average lives of mortgages vary enormously due to differing prepayment rates and lead to significantly different cumulative losses for mortgages with similar credit characteristics. As a result, building an accurate life-of-loan loss model for mortgages is very difficult.

Prepayment modelers take a different approach (as illustrated by the fact that the life-of-loan prepayment rate is a concept unheard of in the industry), using what are called hazard models. A hazard model is simply a model designed to predict the probability of attrition given that the subject has not yet left. For prepayment, this means predicting the probability of prepayment in a given month for all borrowers who have not yet prepaid. This methodology sees heavy use in prepayment modeling. Hazard models for prepayment commonly include age and current rate levels as explanatory variables.

While the hazard modeling is well understood by investors and by Wall Street, technique has less commonly been applied to mortgage default. Hazard models, however, are frequently used in assessing the risk of default or bankruptcy for corporate bonds. In the case of mortgages, a hazard model would predict the probability that the mortgage defaults in a particular month, given that it has not yet defaulted or prepaid. Such a model typically would include age, current house-price levels, and borrower FICO scores as explanatory variables.

One might expect that a default hazard model for mortgages could simply be estimated and then used with an existing prepayment model. As it turns out, however, the two hazards of prepayment and default compete with each other in a way that requires simultaneous development and estimation of the competing risks. The underlying logic is straightforward: Loans that have prepaid cannot default, and vice versa. As a result, any forecast of cumulative defaults must be built up from monthly predictions of both prepayment and default. Moreover, some observed predictive variables, such as the current loan-to-value (LTV) ratio or the FICO score, affect both prepayment and default. For example, increased current LTVs or decreased FICOs likely increase default for mortgages; however, these same variables may decrease prepayment likelihood.

Significant academic and regulatory literature applies the competing risks framework to the hazards of prepayment and default. However, industry use of competing risks models for mortgage prepayment and default is still in its infancy.

Understanding How Prepayment and Default Affect One Another

When there is more than one risk (hazard) affecting survival, they compete. Mortgages face the risk of attrition either from prepayment or from default. Simultaneous estimation of these hazards produces a competing risks model. Competing risks models, like traditional prepayment models, have different implications, depending on the projected economic scenario. Thus, looking at results in different scenarios is the easiest way to understand the interaction of the prepayment and default hazards in a competing risks framework.

Consider Figures 1 through 6, which depict a representative competing risks model applied to a hypothetical pool of loans. The results are illustrative only; however, the relative prepayment and default behavior is reasonable for credit-sensitive mortgages. In each graph, the age of the loan is varied along the x-axis, while the other variables, such as the LTV...
ratio and FICO scores, are held constant.

Figure 1 gives hypothetical conditional prepayment and default rates by age. These conditional rates correspond to an “intensity” rate or “flow” of prepayment and default. Thus, a mortgage still on the books after 23 months has roughly a 3% chance of prepaying in month 24 and a 0.5% chance of defaulting.

Let’s now consider default and prepayment estimates from our competing risks model in a variety of future scenarios. Prepayment in our representative model is strongly affected by interest rates. If the mortgage rate falls below the level current when the mortgage was originated, the conditional prepayment rate rises; if the mortgage rate rises, then the conditional prepayment rate falls. Similarly, several credit-related variables, such as FICO and LTV, affect the conditional probability of default.

The first graph of Figure 2 shows the cumulative prepayments and default rates in a scenario where interest rates increase 100 basis points over one year. The survival curve shows the proportion of the original pool remaining, revealing the level of attrition. The second graph shows the same pool subjected to an interest rate decline.

The cumulative prepayment and default rates obviously are significantly different. In the falling-rate scenario, fast prepayment rates leave far fewer opportunities for loans to default; hence, the cumulative default rate is low. In the rising-rate scenario, however, the increased duration of the pool leaves more opportunity for default; hence, the cumulative default rate is much higher for the same collateral.

The key point of Figure 2 is the inverse relationship between prepayment and default. When rates fall, more loans prepay but fewer default, so overall attrition is less than it would have been had the number of defaults been unchanged. Similarly, when rates rise, attrition slows because of slower prepayment, but the impact is reduced by additional defaults. The effects of prepayment and default on overall attrition are negatively correlated.

Changes in prepayments driven by interest rates not only affect the magnitude (cumulative defaults), but also timing (default incidence), as shown in Figure 3. The two cumulative default curves in the left graph are taken from the earlier pair of graphs in Figure 2. The right graph shows the unconditional probability of default for the two interest rate scenarios. That is, the right graph shows the proportion of the original pool that defaults in each month. The curves initially rise...
because of seasoning, but then fall because the default rates are being applied to a successively smaller pool of mortgages. When rates rise, not only are there more defaults each month, but the peak in defaults occurs later.

Recall that Figure 3 held collateral quality constant, given our hypothetical pool. However, a principal benefit of hazard models is the ability to isolate the effect of pool composition (static characteristics, such as documentation type or original FICO score) from the effect of macro risk factors (dynamic effects driven by interest rates or housing prices).

Imagine, then, two portfolios or underlying collateral pools with different characteristics. The first pool has collateral characteristics (higher LTV, lower coupon rate, low FICO score, etc.) that lead to both lower prepayments and higher defaults, while the second pool has attributes (lower LTV, higher coupon rates, higher FICO score, etc.) that lead to higher prepayments and lower defaults. Figure 4 illustrates the effects of combining interest rate changes with these changes in the underlying collateral characteristics.

Combining low prepayment/high default characteristics with rising interest rates sends the cumulative default rate skyrocketing. Conversely, combining high prepayment/low default characteristics with falling interest rates reduces default rates dramatically.

The Impact of Heterogeneity

A pool of mortgages can be expected to have a range of values for the characteristics that determine prepayment and default. For example, a pool may have an average coupon of 6% and an average FICO of 700; however, the individual loans in the pool likely will have coupons and FICOs that vary significantly from the pool averages. This heterogeneity has a significant impact on pool behavior.

Imagine two pools of loans with identical average characteristics. However, the homogeneous pool is comprised of many identical loans whose individual characteristics are identical to the pool’s average characteristics. In contrast, the heterogeneous pool has the same average characteristics as the homogeneous pool, but is comprised of many loans with differing individual characteristics.

As Figure 5 illustrates, the heterogenous pool has a survival curve that is initially steeper and later flatter than a homogeneous pool, all of whose loans have average characteristics.

Heterogeneity also will cause more lifetime defaults and a different time pattern of defaults than would be inferred by analyzing a homogeneous pool with average characteristics, as illustrated in Figure 6.

This behavior is easily understood. With a mix of loans of different characteristics, the hetero-
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The heterogeneous pool has some loans that are more likely than average to prepay. These loans cause the heterogeneous pool initially to prepay faster than the homogeneous pool. However, once many of these loans have attrited, the surviving loans from the heterogeneous pool are those less likely than average to prepay. Over time, the heterogeneous pool then experiences lesser attrition (greater survival). The remaining slower prepayers, as a result, have more opportunities to default, and they produce a higher lifetime default rate.

To avoid the errors introduced by heterogeneity, analysis of mortgages should be carried out at a fairly detailed level. Analysis of large pools based on average characteristics can produce significant errors. Sometimes, however, disaggregating pools can provide no benefit because loan level detail on predictive variables is not available. In that case, there are statistical techniques available to eliminate the bias illustrated in the graphs.8

The Practical Implications of Competing Risks

Consider for a moment the regular process that banks follow in setting their allowance for loan loss reserves. When projecting the cumulative risk of loss for a portfolio of mortgages (the life-of-loan loss), the expected speed of prepayment must be taken into account. Traditional approaches to estimating loss reserves cannot account for the variability of prepayment speed. Moreover, the competing risks approach naturally provides not only cumulative losses, but also the time pattern for losses. This is important in assessing the profitability of mortgages: Losses taken early have higher present values and reduce profitability more than losses taken later.

In addition, competing risks models, when combined with a projected economic scenario, may yield greater accuracy than traditional loss-reserving approaches. Of course, this requires the forecasting of economic variables like interest rates and house prices, and economists’ success in forecasting these variables has been limited.9 At a minimum, however, competing risks models can provide accurate cumulative loss estimates given the economic scenario. Thus, an analyst can try out several plausible scenarios to understand the range of cumulative losses. At a more sophisticated level, financial economists have been more successful in projecting the future probability distributions for interest rates and house prices. Thus, performing Monte Carlo analysis based on these distributions provides statistically valid estimates of the entire probability distribution of cumulative losses. MBS investors

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Figure 5  
Joint Survival Rates

![Joint Survival Rates](image)

Figure 6  
Cumulative Default Incidence

![Cumulative Default Incidence](image)
use this approach when valuing MBS by combining a hazard model for prepayment model with Monte Carlo simulation of interest rates.

The competing risks concept also has implications for the process of capital allocation for mortgage portfolios. If the size and timing of losses vary with the speed of prepayment, then, in principle, capital requirements should reflect that. Currently this is not the case, at least with regard to regulatory capital for financial institutions. The Basel II regulatory capital requirements for mortgages are based on the same theoretical approach—a Merton-type model based on a single risk factor—as is used for other consumer loans and for commercial loans.

The Basel regulatory framework therefore ignores the impact of prepayment on cumulative losses. Moreover, the single-factor approach attempts to reduce the impacts of varying risk drivers—interest rates, house prices, employment, etc.—to one factor. Though banks and thrifts must calculate regulatory capital according to the Basel guidelines, they often perform their own calculations of economic capital for use in specific portfolio management and pricing decisions. Given the results shown herein, economic capital estimates clearly should account for the competing risks of default and prepayment.

As another implication, the competing risks framework may offer mortgage investors some additional flexibility in the way they manage risks. Financial institutions manage credit risk by allocating capital to absorb unanticipated losses with the amount allocated sufficient to cover any loss up to some threshold with only a very small probability of occurrence. Prepayment risk, on the other hand, is treated as a component of market risk and managed at an overall balance sheet level because there are often offsetting positions within the balance sheet. If there is net market risk at an overall level, it may either be accepted or offset by hedging in wholesale financial markets.

The negative correlation between losses and prepayment and default, as measured using the competing risks framework, should reduce the market risk of mortgages. In principle, overall credit risk could be broken into two components: one that is negatively correlated with prepayment risk and another that is uncorrelated. Netting the correlated component with prepayment risk will reduce its contribution to overall market risk. The remaining uncorrelated component of credit risk then would be smaller than overall credit risk and produce smaller expected and unexpected losses.

As a final point, the intertwined nature of prepayment and default for mortgages may have consequences for governance in financial institutions. Credit risk management and market risk management have usually been separate functions. For many financial products this is completely appropriate, and even for mortgages, many of the functions of credit risk management and market risk management are unrelated. However, for mortgages, prepayment and default are competing risks. For institutions with significant mortgage portfolios, some coordination of credit and market risk management could pay dividends.

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Notes

1 In contrast, the two GSEs put only $188 billion in conforming mortgage risk on their balance sheets during the same period.

2 For a background of various approaches to modeling consumer default, see Lundstedt, K., “Credit Models in Banking: Past, Present, and Future,” a presentation given at the OCC Conference on Credit Rating and Scoring Models, May 2004.


9 As the story goes, three economists went out hunting and came across a large deer. The first econometrician fired but missed, by a meter to the left. The second economist fired but missed, by a meter to the right. The third economist didn’t fire, but shouted in triumph, “We got it! We got it!”