A note on prepayment modelling for residential mortgages

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Introduction

Banks with mortgage portfolios face the risk of early prepayments of these mortgages. Early prepayments result into substantial interest rate risk, since in this case the duration of the mortgage portfolio becomes stochastic. This can lead to significant mismatches between the expected and actual cashflows, which is shown in the figure below, which depicts the cashflows without and with prepayments on a 100K of a typical 30-year mortgage portfolio.

With the increased scrutiny that banks face as the result of sharpening IRRBB standards, the proper modelling of the mortgage prepayment risk becomes more and more important. Probability & Partners has a significant expertise in modelling the prepayment risk for Dutch residential mortgages. In this note we briefly review the main prepayment modelling methodologies, main factors affecting prepayment risk and outline some other related issues such as hedging of prepayment risk and the associated model risk.
Long history

Mortgage prepayment modelling has a rather long history: both academics and practitioners were modelling prepayments already in the 1980s-1990s. This was done predominantly on the individual mortgage level. The renewed interest in mortgage prepayment modelling coincided with the phenomenal popularity of Mortgage-Backed Securities (MBS) in the late 90s and early 2000s, and in this case the prepayments were modelled for the entire mortgage portfolio. These two modelling approaches are quite distinct (i.e., on the individual or on portfolio level), as many heterogeneities among mortgages average off when viewed in the portfolio context. We will elaborate on this issue briefly below.

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Is more an art than the science”

Modelling prepayments of residential mortgages is more an art than the science. This is because many factors affect prepayments, and these factors influence prepayment behaviour in different ways, depending on economic circumstances. Moreover, the crucial element in creating a good model for prepayment risk of your mortgage portfolio is the availability of extensive and high quality historical data on the past mortgages and their prepayments – something many banks struggle to generate.
Types of models for prepayments

The two by far most used models for prepayments are the Proportional Hazard (PH) model and Logistic Regression (LR) model.

Proportional Hazard model

The Proportional Hazard model, introduced by Cox in 1972, originates from the analysis of survival data (survival times of e.g., cancer patients under various types of treatment). Cox PH model is the most famous statistical model and his 1972 paper is one of the most cited papers in the world. In the Proportional Hazard model, the quantity of interest is the (random) time to event, usually death, and the distribution of this event time is characterized by the so-called hazard rate, which is the probability of the event occurring in the next small time interval, given it has not occurred before. The hazard rate is modelled as the product of the so-called baseline hazard, which describes the time development of the “typical” hazard rate of an average patient, and a multiplier, containing the influence of patient-specific variables, such as gender, age, biometric characteristics and, most importantly, the type of treatment.

In prepayment modelling, the event is the prepayment of the mortgage and we model the hazard of prepayment occurring in the next month, given the mortgage has not been prepaid yet. The baseline hazard rate is then the “typical” prepayment profile, which usually depends on the age of the mortgage and exhibits the so-called S-shape, indicating that newly initiated mortgages and those mortgages close to expiration have lower repayment rates than those in between. The multiplier of the hazard rate contains mortgage-specific factors which we will outline below.

The attractions of the PH model are numerous. First of all, its estimation procedures are well-developed, even in cases when the data is incomplete. Second, it has a massive interpretability, whereby we can pinpoint and quantify in a very intuitive way the influence of various factors on the likelihood of prepayment. Finally, the model is very flexible, in terms of inclusion of time-varying factors and parameters, commonality and specificity factors and so on. Despite all these attractions, the PH model is not as widely used by banks for modelling prepayments, due to its relative complexity and unfamiliarity of finance professionals with this model, since it comes from medical sciences. This in our view is a pity, because it is a great model and our experience with prepayment modelling shows that it produces superior results to other (e.g., logistic regression) models.

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Logistic Regression model

The logistic regression (its logit or probit variant) is another widely used model for prepayments. The response (or the dependent variable) in such a regression model is a binary variable, indicating the occurrence of a certain event (prepayment in this case). The regressors or independent variables are the mortgage-specific as well as overall economic factors, as in PH model. It can be shown that in some cases (e.g., low hazard rates), the logistic regression model is close to PH model.

After fitting the LR model to the historical data, we can plug in characteristics of a new mortgage into the model, together with the economic factors, and the outcome of the model will be the probability that the mortgage will be prepaid early.

The logistic regression is a tool widely used in banks already (e.g., in default modelling and credit scoring), hence it is more popular model among practitioners for prepayments. However, it often lacks the flexibility and interpretability of the PH hazard model, and in our experience with prepayment modelling, can produce inferior results when compared to PH model.
Factors affecting prepayments

To understand which factors affect prepayments of residential mortgages, it is important to understand what causes early prepayments. These causes are, among others, defaults of mortgage holders, refinancing the mortgage at a different bank to take advantage of lower interest rates, selling the house due to divorce or moving to a different region or different house and so on. These causes of early prepayments are related to three classes of explanatory factors:

- Refinancing factors (interest rates, mortgage rates, penalties etc.)
- Macroeconomic factors (housing market, business cycle, demographics etc.)
- Microeconomic or loan-specific factors (age of mortgage and mortgage holder, type of mortgage, type of house, loan to value ratio, socio-economic status of mortgage holder and so on).

For **refinancing factors**, the interest rate-related factors are the most important. These are not only the absolute levels of interest rates, but also the historical momentum of rates, steepness of the yield curve. Here also loan-specific information is important, such as interest reset dates and the rate differential.

In terms of **macroeconomic factors**, the overall state of the economy/business cycle is the most important determinant as it reflects both housing booms and default rates. Seasonality is important too, with most prepayments occurring in Q4. Demographic factors also play important role here.

Finally, there is a myriad of **micro or loan-specific factors** which can have large but varying effect on prepayments in different refinancing or macroeconomic conditions. Here we face the biggest modelling challenge: collecting the micro data on individual mortgages and deciding which ones are more important than others. One can avoid this modelling challenge by considering prepayment risk on the portfolio level, assuming that in a well-diversified mortgage portfolio these factors will average out. In this case, only macroeconomic and refinancing factors should be taken into account. However, this is a major assumption which, if not satisfied, can lead to a massive underestimation of prepayment risk. So our advice would be to try to take as many as possible micro factors into account.
Other factors

Obvious important factors are age of the mortgage and of the mortgage holder, the interest rate differential between market and mortgage rates. However, other factors can be of influence too, and this is very country- and time-specific. For example, in one of our previous projects on modelling prepayments for a major bank we found that the type of property is important, as prepayments associated with apartments are much higher than those associated with houses, and we were able to determine exactly how much higher the risk of early prepayment is in this case. The loan type is important too (annuity, investment, savings mortgage or other), as is the socio-economic status of the mortgage holder. We modelled the prepayments for another Dutch bank, and that bank has provided us with the postal code of the mortgage holders, which can be used as a proxy for the socio-economic status. We found that there are significant differences between likelihood of early prepayments between middle, low and high income mortgage holders and we were able to quantify these differences in terms of % increase of prepayment likelihood.

“In all, micro factors modelling is a challenging task, also because one has to deal with possible dependencies and collinearities between the factors. On the other hand, the proper modelling of early repayments on the loan level gives a bank a very detailed and specific information about prepayment risk”.

Related issues: hedging and model risk

Apart from modelling the prepayment risk, the question arises: is it possible to hedge this risk? The answer is yes, and for this purpose the so-called Index Amortizing Swaps can be used. These are over-the-counter (OTC) interest rate derivatives, similar to the usual Interest Rate Swap, but where the notional underlying the swap amortizes according to a certain rate or a schedule, which can be explicitly dependent on the reference interest rate. To negotiate such a swap with a dealer bank, one would need a good prediction of portfolio prepayment rate through time, to specify the amortization of the swap principal. Alternatively, one could specify how the portfolio prepayment rate depends on the changes in the interest rate. Both these goals can be achieved by using the methodology outlined above.

Finally, according to the latest model risk directive (TRIM), the banks must address the model risk associated to all their models, so also to the prepayment model they use. We have done considerable work in this area, specifying and quantifying model risk associated with early prepayment models.

To find out more about our expertise in these and related areas, and about how Probability & Partners can help you with modelling prepayment risk and your other IRRBB needs, please contact:

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