A Study of Mortgage Prepayment Risk

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Barclays

Bradford & Bingley

Bristol & West

Halifax

Nationwide

At the end of 2000, the combined market share of these lenders represented about 65% of outstanding mortgages in the UK. A detailed report on the drivers of prepayment behaviour in fixed rate mortgage portfolios was produced for the participating lenders.

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EXECUTIVE SUMMARY

As recently as five years ago the average tenure of a residential mortgage in the UK was around seven years. Most lenders will tell you that the equivalent figure today is nearer four, due mainly to consumers' increased willingness to switch lender for a better deal. This is a worrying trend for lenders since, because of the high costs of acquiring a mortgage, mortgages typically need to remain on the books for several years in order to be profitable.

Fixed rate loans, which account for around one third of UK residential mortgages, typically have even shorter lives. They pose a particular problem for lenders, because of the financial impact of early repayment on their funding arrangements. Because of the significance of this problem, eight of the top ten lenders, representing over 65% of the nation's outstanding loans, participated in this six-month long study, providing the necessary data for analysis.

The work undertaken explores both the causes and the results of prepayment of fixed rate mortgages. The techniques employed shed new light on the reasons why customers repay ahead of schedule. They advance the industry's understanding of the circumstances in which prepayment is most and least likely.

Four drivers are shown to have a significant impact on prepayment behaviour:

- Age of the fixed rate loan – From the point at which a borrower takes out a fixed rate mortgage, it usually takes some time for a significant interest differential to appear. And after having gone through the process of applying for one mortgage, few borrowers immediately look to re-mortgage again. Prepayment rates generally rise in the second half of the fixed rate period, but tail off before the end of the period.

- House price inflation – When house price inflation is high the number of home moves increases. Increased activity in the housing market results in increased prepayment.

- Interest differential – This measures the tangible saving that a borrower could make by switching to another fixed rate or variable rate mortgage. A high interest differential encourages borrowers to prepay, but the effect of interest movements is far from linear.

- Prepayment charges – These charges create a cost to prepayment that acts as a disincentive to prepay. We observed that charges over a certain level appeared to discourage prepayment significantly.

These four factors interact with each other and with a number of other variables to determine the likelihood of early prepayment.

As well as exploring the causes of prepayment, this study considers the impact of prepayment on profitability and value creation and shows how techniques such as projection modelling, predictive modelling and stochastic modelling can be used to manage prepayment risks better. In doing so, it points towards ways of reducing prepayment risk through product design, pricing and customer retention initiatives.

INTRODUCTION

1.1 Background and motivation

An investigation of mortgage prepayment risk in fixed rate loans was chosen as the subject of this study after discussions with the banking community because the issue was of current interest to banks, due to:

- Downward pressure on early prepayment charges
- A move to flexible products with charge free withdrawals
- Increased propensity of customers to remortgage

Mortgages are similar in nature to many of the insurance products that are routinely modelled as they are long-term products (typically 25 year) and typically have high up-front acquisition costs.

1.2 Intended audience

In this study, we have analysed the relationships between a number of potential drivers of prepayment behaviour and developed models that predict prepayment behaviour. Our analysis will be of interest to banking professionals with an interest in:

- The management of prepayment risk exposures
- The design and pricing of mortgage products
- The development of customer retention initiatives

1.3 Scope of this study

For the purposes of this study, we have defined prepayment risk to be the risk of loss to the lender due to early repayment by the borrower of all of a fixed rate loan before the end of the fixed rate period. The prepayments can occur under four circumstances:

- Refinancing – A borrower may decide to move to a new mortgage that offers a better rate
- Repayment – A borrower may decide to repay their mortgage early using, for example, savings, a bonus or a windfall

- Moving house – A borrower may terminate an existing mortgage when moving to a new property
- Default – A borrower who defaults on a mortgage has in a sense made a prepayment, as the lender has to recover the funds and invest them elsewhere

In this study we have focused on analysing the behaviour of borrowers who intentionally prepay their loans. We have, therefore, excluded borrowers who defaulted. Further, borrowers often choose to prepay part of their loan early. We have not analysed partial prepayments in this study.

1.4 Overview of this report

The remainder of this report is organised into the following sections:

- Section 2 provides an overview of mortgage prepayment risk, intended as an introduction for readers who are unfamiliar with the UK mortgage industry and/or prepayment risk. Others may prefer to skip this section.
- Section 3 contains a high-level description of the control cycle framework adopted in this study. In particular, the framework consists of three major elements. The way we have applied each of these to mortgage prepayment risk is described in sections 4, 5 and 6.
- Section 4 describes how profiling is used to illustrate the impact of the various factors believed to have potential to drive prepayment behaviour and describes some of the most significant factors.
- Section 5 describes the application of two types of predictive modelling.
  - Section 5.1 shows how causal predictive models of those customers and accounts with the highest risk of prepayment can be developed
  - Section 5.2 uses projection methodology to quantify the expected impact of prepayment on value creation
- Section 6 covers some of the ways that these analyses and models can be used in the day-to-day management of prepayment risk, by:
  - Understanding the required level, and potential impact on profitability, of prepayment fees and charges

- Understanding how the funding requirement can be proactively adjusted based on predictive modelling, and the associated costs and risks
- Identifying those customers and accounts with highest prepayment risk in order to design products and develop customer retention initiatives that minimise prepayment risk

- Section 7 summarises our conclusions and includes some suggestions for further research.

2. AN OVERVIEW OF PREPAYMENT RISK

To provide some background information for readers new to prepayment risk, this section explains how prepayment risk is created in fixed rate mortgage portfolios, considers why prepayment risk has proved difficult to model and looks at how lenders have tried to manage prepayment risk. Readers who are familiar with these concepts may wish to jump to section 3.

2.1 The creation of prepayment risk

Lending money for a fixed period at a fixed rate can create interest rate and liquidity risks that need to be managed by the lender. Interest rate risk arises where the interest rate paid on the funding for a loan may change over time while the interest rate on the loan is fixed. Liquidity risk occurs where the funding for a loan has been borrowed for a time period that is shorter than the life of the loan. These risks can be managed in two ways:

- The lender can fund the loan with an asset that has a fixed interest rate and the same maturity. For example, five year investment bonds with a fixed interest rate could be issued to raise money to fund five year fixed rate mortgages. This approach mitigates interest rate and liquidity risk.

- Or an alternative option is to eliminate the interest rate risk exposure by using a series of forward interest rate agreements. This approach will eliminate interest rate risk but does not eliminate liquidity risk.[1]

Regardless of which funding and risk management technique is adopted, the lender is committed to borrowing the funds required for the mortgage at a fixed interest rate (or rates) over a fixed time period. If, at any point in the fixed rate period, the borrower repays the loan early, the lender will have to find an alternative use for the funds. If interest rates have gone up since the original loan was made, the lender will be able to re-lend the surplus funds or close the forward rate agreements at a profit. However, if interest rates have fallen, the lender will have to re-lend the funds or close the forward rate agreements at a loss. This risk of loss only exists because of the action that the lender has taken to eliminate the original interest rate risk exposure. It is this risk of loss due to early repayment that is referred to as prepayment risk.

2.2 Modelling prepayment risk

There is a large body of academic and industry research analysing mortgage prepayment risk, much of which is based on US mortgage data. Early analysis in the US focused on the relationship between interest rates and the prepayment option held by the borrower. Many of the models developed assume that there are two types of prepayment:

- Optimal (or systematic) prepayments – These prepayments are made when interest rate movements mean that it is rational to refinance.
- Sub-optimal (or unsystematic) prepayments – These prepayments are made because of changes in the circumstances of the borrower (e.g. death, divorce, inheritance, etc.) and are independent of interest rates. They can be estimated from empirical analysis and can therefore be planned for and managed.

These models clearly demonstrate that interest rate changes have a significant impact on prepayment rates. However, they typically assume that borrowers will exercise their prepayment option rationally. In practice, empirical analysis of prepayment rates for different mortgage portfolios experiencing the same interest rate changes shows that prepayment rates vary considerably across portfolios. Subsequent research, over the last two decades, has focused on developing multi-factor models that are better predictors of prepayment rates. The main challenge is to explain why different sub-sets of broadly similar borrowers behave so differently.

This body of work provides some interesting theoretical approaches for considering prepayment behaviour. However, there are a number of significant differences between the US and UK mortgage markets. In the US, the mortgage lending process is split into three distinct segments: origination (lending), servicing and funding. US mortgage lenders typically choose to focus on origination and/or servicing, whilst the vast majority of mortgages are funded through securitisation. In the UK, some lenders have begun to separate these different activities, but many still perform all three. The fixed rate mortgage products sold in the US are also very different from those sold in the UK. US fixed rate mortgages offer a fixed rate for the life of the mortgage (typically 25 years). UK fixed rate mortgages offer a fixed rate for a short period (typically 2 to 5 years) and then revert to a variable interest rate. Care should therefore be taken when making inferences about prepayment behaviour in the UK based on US experience and analysis.

2.3 Managing prepayment risk

Lenders have developed a variety of strategies to deal with prepayment risk. There are three core approaches:

- Adjusting the funding requirement – This approach assumes a certain level of prepayment is inevitable and attempts to adjust the funding for a portfolio of loans accordingly. Consider a fixed rate mortgage portfolio with an expected monthly prepayment rate of 1% in its first year. When funding this portfolio, the lender would simply assume that the fixed rate funds required reduced by 1% per month. Provided observed prepayment experience exactly matched initial expectations there would therefore be no loss due to prepayments. This strategy is widely used to plan for unsystematic prepayments.

- Recovering the cost in the event of prepayment – These approaches are designed to recover the loss made by the lender when the borrower prepays through a prepayment charge. Two different charging structures have been used in the UK:

  - Fixed charges – Typically a certain number of months' interest payments on the mortgage. The number of months of interest charged varies by lender.

  - Mark-to-market charges – These charges calculate the cost of reinvesting the surplus funding or closing the forward rate agreements at the time the borrower prepays and charge the borrower that amount.

- Charging all customers up-front for the prepayment option – This approach relies on charging the borrower an up-front fee for the cost of the prepayment option embedded in the fixed rate mortgage. This approach is common in the US, but we are not aware of any lenders in the UK using it.

By using one or more of these approaches, lenders can reduce their exposure to prepayment risk. In the UK, lenders typically adjust their funding requirement in expectation of a certain level of unsystematic prepayment and use prepayment charges. This dual approach protects against systematic and unsystematic prepayments. Mark-to-market charges provide the best defence against prepayments, as they completely cover any loss. Fixed prepayment charges

are easier to use, but do not eliminate all of the risk, as it is possible that the loss to the lender will be greater than the charge.

However, whilst it is possible to eliminate exposure to prepayment risk in theory, it has proved difficult in the UK to do so in practice. In recent years, consumer activism, regulatory scrutiny and competitive pressures have combined to make it difficult to eliminate prepayment risk:

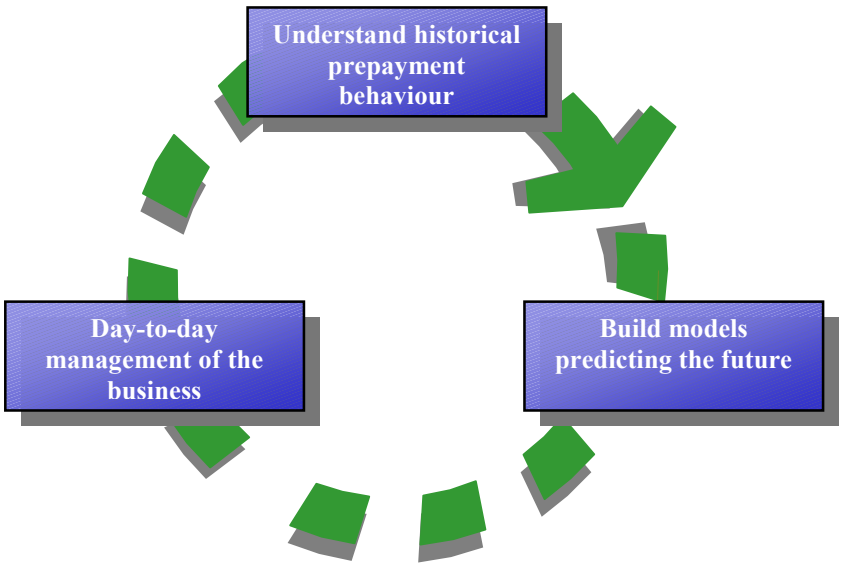
- The financial press routinely advises borrowers to look for mortgages with better rates without prepayment charges and the Internet makes it easy to find these products.
- Borrowers have successfully challenged mark-to-market charges by claiming that they did not understand them when the mortgage was sold. Following the intervention of the Office of Fair Trading, it is now doubtful whether many of these charges are enforceable.
- And, as the mortgage market becomes increasingly competitive, some lenders have introduced a facility to prepay between 10% and 15% of the loan per annum without charge.

In the past, the use of prepayment charges meant borrowers had to pay to exercise the prepayment option that they were given. The fact that it was difficult to quantify how many borrowers would prepay was therefore less of an issue for lenders. In the future, lenders are unlikely to be able to recover the full cost of borrowers exercising their prepayment option. That means understanding the drivers of prepayment behaviour and taking steps to reduce prepayment rates will become increasingly important to the profitability of fixed rate mortgage lending. This study explores how lenders can utilise appropriate techniques to address these issues.

3. APPLYING A CONTROL CYCLE FRAMEWORK TO PREPAYMENT RISK

The risk management framework used in this study is built around a control cycle, illustrated in Figure 1 below.

Figure 1 – A control cycle



The approach is based on the application of a scientific method to risk management:

- First relevant historic data is collected, cleaned and analysed
- That data is then used to develop predictive models of the business
- Those models are then used to manage the risks faced by the business

These three steps, as applied in this study, are described in sections 4, 5 and 6 respectively of this report.

The control cycle is an iterative process – as additional data and more sophisticated modelling techniques become available, models are refined and the risk management process is improved. Likewise, the management of risk in this way will tend to identify new questions that need to be answered, requiring more data and more analysis. In this study, the control cycle was used to provide a framework for the analysis of prepayment behaviour. At each stage in the cycle, a range of techniques has been used to analyse and model prepayment behaviour.

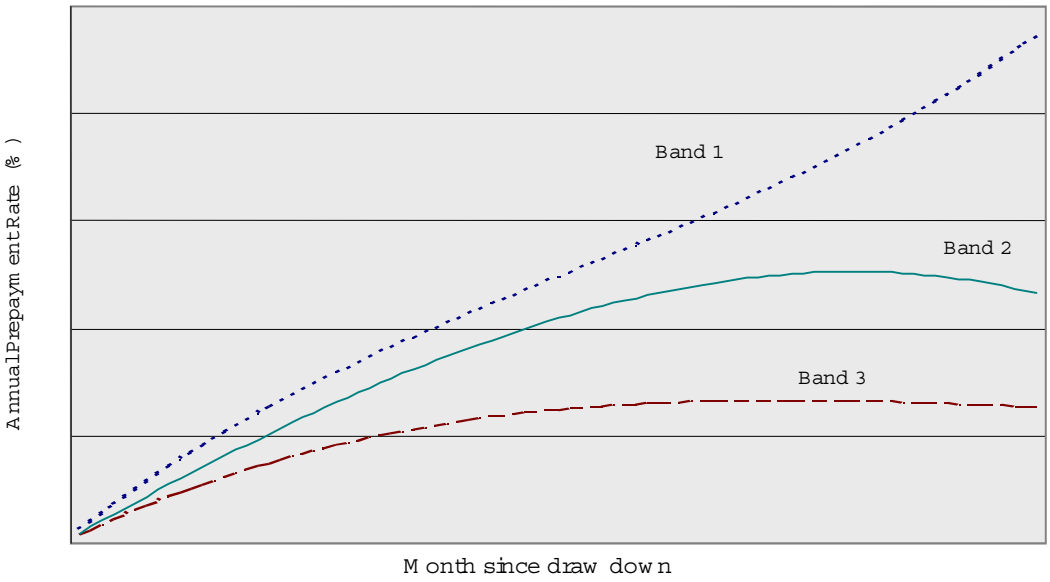
4. UNDERSTANDING HISTORICAL PREPAYMENT BEHAVIOUR

The first step in the control cycle is to understand the lessons of the past. Following discussions with the participating lenders and a review of academic and industry research, a number of potential drivers of prepayment behaviour were identified. This section looks at how the potential prepayment drivers were analysed, discusses the different drivers that were considered for analysis in the study and summarises the impact of the key drivers identified. The actual output from the analysis has been supplied to the participating lenders. This report is deliberately less detailed than the results provided to participants, in order to protect the commercial interests of those lenders who supplied data in confidence.

4.1 Analysing potential prepayment drivers

To investigate which of the drivers suggested might be significant, the data supplied by the lenders was segmented by the identified key variable and prepayment rates for different subsets of the data pool were plotted. An illustrative example of the resulting charts is shown in figure 2.

Figure 2 – Illustrative prepayment rate profile



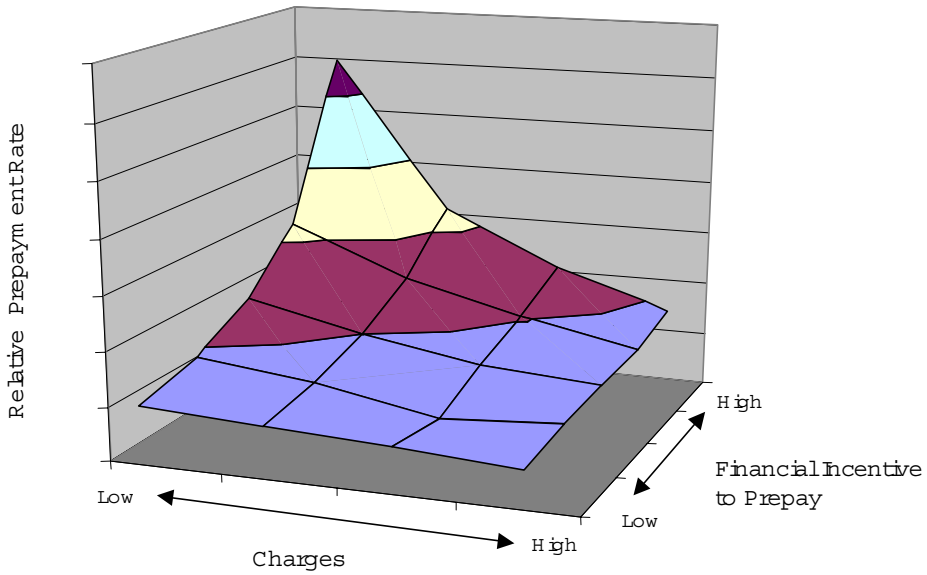
We refer to these charts, which plot changes in a variable over time, as profiles. These charts are typically used to investigate possible drivers of lapse rates on general and life insurance policies and mortality rates for life insurance policies. In this particular chart, the data for 5 year fixed rate mortgages is segmented according to how high the incentive to refinance was

in each month of the life of the loan[2]. The three bands show how prepayment rates vary over time for different levels of incentive to prepay. Band 1 shows prepayment rates for those mortgages where the incentive to refinance was highest while Band 3 shows prepayment rates for those mortgages where the incentive to refinance was lowest. This chart suggests that there is a strong relationship between the incentive to refinance and the number of customers prepaying.

However, we also note that there appears to be a relationship between the length of time that a customer has had the fixed rate mortgage and the prepayment rate. In each of the three scenarios, prepayment rates are lower at the start of the fixed rate period. This reflects the fact that borrowers who have only just taken out a mortgage are unlikely to switch lenders or move house again immediately. However, over time circumstances will change and people may need to move again or decide to remortgage. It also takes time for interest rates to move sufficiently to create a financial incentive to remortgage. These two factors result in an upward sloping curve to prepayment rates over time. It should be noted, however, that the behaviour observed in figure 2 above will change under different economic scenarios. In particular, changes in the financial incentive to prepay were observed to have a non-linear impact on the prepayment rate.

Prepayment rates can be plotted against a number of different variables. Figure 3 looks at the interaction between the financial incentive to prepay[2] and the charge made on prepayment. While lenders tend to use charges as a means to recover the cost of prepayment, this chart suggests that charges can also discourage prepayment. Where charges are low and the financial incentive to prepay is high, the relative prepayment rate is high; but when charges are high, prepayment rates remain low even when there is a strong financial incentive to prepay.

Figure 3 – Relationships between key variables



4.2 Potential prepayment rates that were investigated

Below we list a selection of the potential drivers of prepayment behaviour that were identified in this study. The time and resources available to perform this study prevented a full investigation of all the potential drivers identified. Some potential macro economic drivers were excluded from the analysis either because other drivers were believed to be a better alternative, or because previous analysis has shown them to be of limited importance. The vast majority of borrower specific drivers were also excluded due to concerns about the confidentiality of customer data on the part of the participating lenders. The large number of potential drivers listed illustrates why prepayment risk has proved so difficult to model.

- Macro economic drivers:
  - Interest rate changes - The difference between the fixed interest rate paid by the borrower and alternative interest rates available was explored as a measure of the financial incentive for the borrower to prepay.
  - House price inflation (HPI) - HPI was explored to see if high HPI encouraged borrowers to move house more frequently or, conversely, if low or negative HPI discouraged borrowers from moving[3].

- Growth in GDP – GDP growth was suggested as a driver to see if the general health of the economy was linked to prepayment rates.
- Employment levels – Employment statistics were suggested as a driver to see if the general health of the economy was linked to prepayment rates.

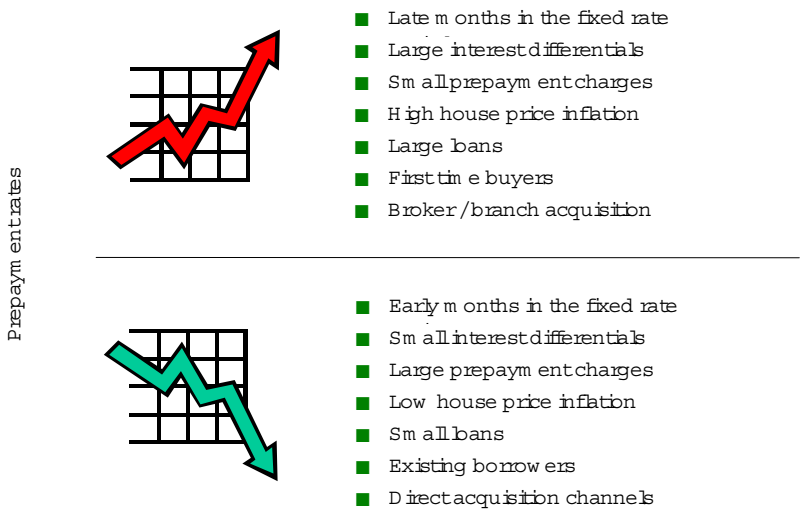
- Loan specific drivers:
  - Age of loan (time into the fixed rate period) – The number of months that the borrower had had the fixed rate mortgage was investigated as a potential driver of prepayment.
  - Length of fixed rate period – for example, a mortgage with a 3 year fixed rate period could exhibit different prepayment rates from one with a 5 year fixed rate.
  - Loan to value ratio (amount borrowed as a percentage of the value of the property at drawdown) – The loan to value ratio was explored as a proxy for the affordability of the loan.
  - Structure of prepayment charges Prepayment charging methods were investigated to explore whether the size of the charge and the way that the charge was made discouraged prepayment behaviour.
  - Sales channel (branch, telephone/internet and third party) – Sales channel was explored to see whether prepayment rates differed by channel, either because different types of borrower selected particular channels, or because interactions with the lender's staff or third party advisers encouraged or discouraged prepayment[4].
- Borrower specific drivers:
  - Age of borrower – This driver was suggested to see if borrowers at different stages in their lives were more or less likely to prepay.
  - Marital status of borrower – One reason that sub-optimal prepayments occur is properties being sold to divide assets when couples divorce. Marital status was suggested as a driver that might show this effect.

- Region where the borrower lives – Region was suggested as a driver to see whether prepayment rates changed significantly due to regional differences in macro-economic drivers and borrower specific drivers.
- Occupation of borrower – Occupation was suggested as a driver to see whether differences between borrowers due to salary, job and financial literacy, etc., increased or decreased prepayment rates.
- Borrower type (first time buyer, existing customer and remortgage customer from another lender) – These borrower classifications are commonly used in the mortgage industry. Borrower type was explored to see whether classifying borrowers in this way revealed any difference in prepayment rates.
- Ratio of loan to salary of borrower – This variable was suggested as a more sophisticated measure of the affordability of the loan.
- Other products held with the lender by the borrower – This variable was suggested to see whether borrowers who had a strong relationship (other products) with the lender were more or less likely to prepay.

4.3 Summary of key drivers identified

Analysing the relationships between potential drivers of prepayment behaviour using profiles can help to identify drivers that should be analysed in more detail using statistical techniques. Figure 4 summarises the directional impact on prepayment rates of the key drivers identified from the data profiling. Participating lenders have been provided with more detail about the magnitude of impact and relative importance of these factors.

Figure 4 – Impact of prepayment drivers



The profiling suggested that the drivers that appeared to have the most significant impact on prepayment behaviour were:

- Age of the fixed rate loan – Having already gone through the process of applying for one mortgage, it is also reasonable to assume that most borrowers would not be immediately looking to re-mortgage or move house again. Hence, the fact that we observed prepayment rates to be higher in the second half of the fixed rate period than in the first half seems sensible. Also, from the point at which a borrower takes out a fixed rate mortgage, it takes time for a significant interest differential to appear and therefore this is captured within the point below.

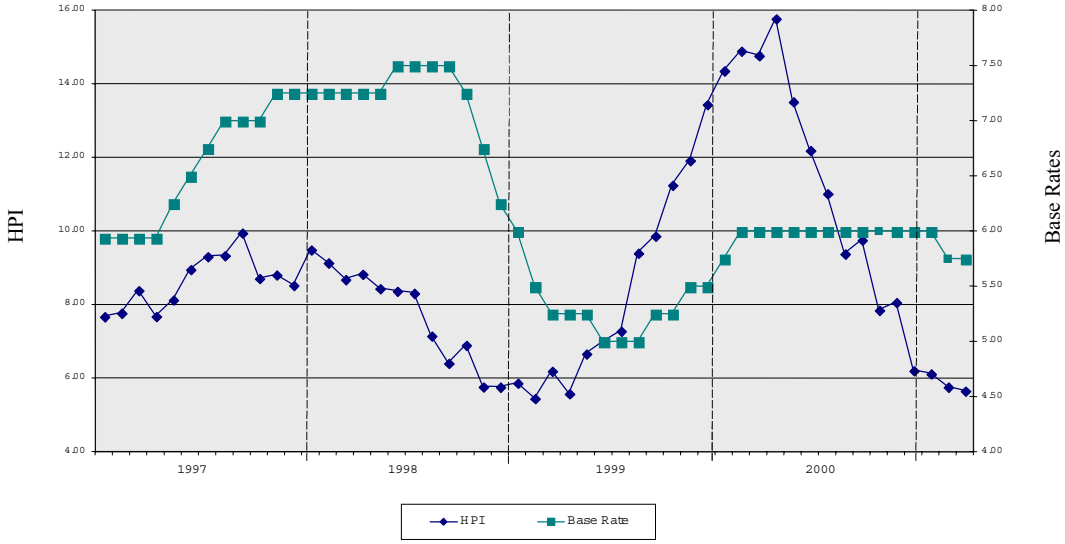
- House price inflation – When house price inflation (as measured by indices provided by Halifax plc and Nationwide Building Society) is high the number of home moves increases. We would expect this increase in activity in the housing market to result in increased prepayment and this was observed in practice.

- Interest differential – This variable gives an indication of the tangible saving that a borrower could make by switching to another fixed rate or variable rate mortgage. It is therefore logical to suppose that a high interest differential will encourage borrowers to prepay and this was observed in practice.

- Prepayment charge – The prepayment charge creates a cost to prepayment that acts as a disincentive to prepay. We observed that charges over a certain level appeared to discourage prepayment significantly.

The other drivers explored were found to be less significant. The importance of changes in base rate and house price inflation as drivers of prepayment behaviour is illustrated below. Figure 5 shows how house price inflation and base rates have moved since 1997.

Figure 5 – House Price Inflation and Base Rate Movements



For example, looking at this chart, we would expect prepayment rates to be higher in 2000 than in 1998. This is because by 2000 base rates had fallen from their 1998 level, creating an interest differential, and house price inflation was higher than in 1998. Table 1, below, shows normalised prepayment rates for five year fixed rate mortgages for 1998 and 2000. We can see from this data that prepayment rates did move as we expected.

Table 1: Normalised Prepayment Rates for Five Year Fixed Rate Mortgages

	1998	**2000**
Prepayment Rate (normalised)	100	166

5. DEVELOPING PREDICTIVE MODELS

The analyses described in the previous section are backward-looking. In this section, we consider how they can be used to develop forward-looking, predictive models. Two types of predictive model are described:

- In section 5.1, we describe how we develop predictive models that allow those customers with the highest risk of prepayment to be identified.
- In section 5.2, we describe how we quantify the expected impact of prepayment on the value created by the business using projection models.

Finally, even the best predictive models cannot guarantee to project what will actually happen in the future. In section 5.3, we describe how to use a stochastic model to generate a whole range of possible economic scenarios and calculate the prepayment costs associated with each of them to understand the possible size and distribution of prepayment costs, and hence determine an appropriate risk management strategy.

5.1 Predictive models of prepayment behaviour

The prepayment profiles illustrated in section 4 reflect the prepayment rates in the mix of business actually written and modelled. Consequently they are a biased estimate of the prepayment rates and although the profiles are informative, they do not identify causal relationships between variables. This bias remains even when sub-segments of the data are profiled, as the profiles still reflect the impact of multiple drivers on prepayment rates.

The objective of this phase of the project was to build a (predictive) model that segmented mortgage customers into clusters with a similar risk profile. Further, the model should identify factors (e.g. product or customer characteristics) that "explain" the risk profile of each cluster. In principle, to identify causal relationships various statistical or regression techniques that model the full distribution of all the variables can be applied. Since this problem is similar to the problem faced by motor insurers who have to classify motor insurance customers using customer characteristics that predict the likelihood of an insurance claim, we developed a motor insurance-style "rate card" to explain the prepayment risk in the mortgage portfolio.

The rate cards were developed using Generalised Linear Modelling (GLM) techniques. GLM is one of a number of statistical techniques that could be used to develop predictive models of

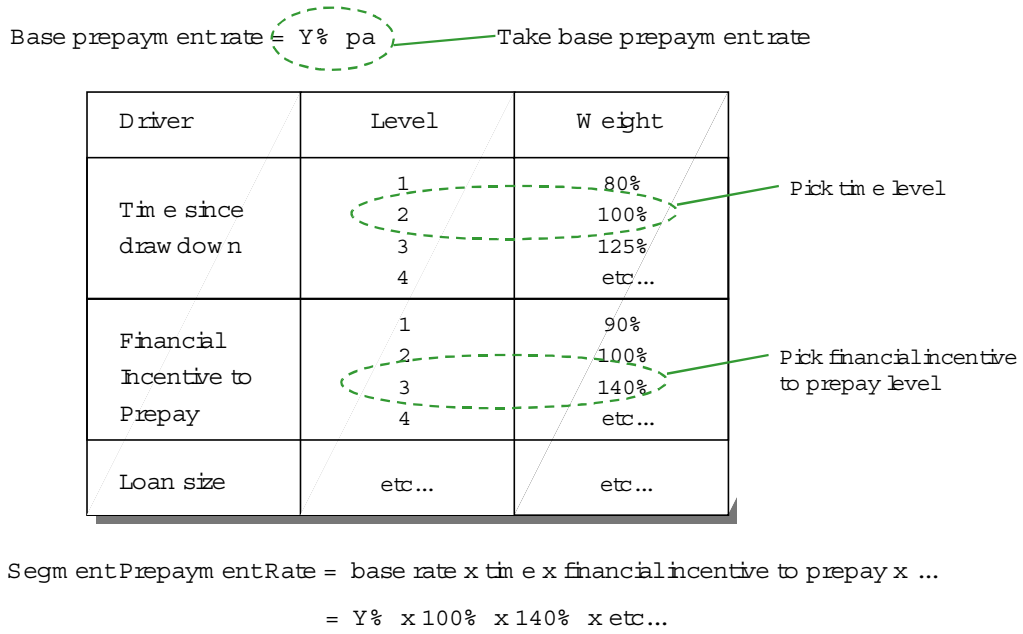
prepayment risk[5]. A GLM model estimates the impact of changes in individual drivers on prepayment rates whilst holding all other drivers constant. It is therefore able to identify relationships between changes in prepayment rates and changes in the underlying driver. The predictive modelling process builds from the insights gained from the profiling of the prepayment rates which illustrate the variables we anticipate proving significant in the statistical modelling. However, it is quite possible that some of the drivers are not as significant as they appear to be and other variables are responsible for the changes in prepayment rates observed when they were plotted. In principle, there is therefore no reason why a variable that appeared significant when charting the data should remain so when analysing it statistically.

A standard GLM iterative modelling approach was used, with a single loop as follows:

- A base prepayment rate that represents the average prepayment rate for a typical customer is calculated.
- Then the factors (for example ranked using their Chi-squared value) that cause deviations in the prepayment rate are identified.
- The impact of changes in each of the main factors on the prepayment rate is estimated.
- An error test is used to check the "goodness of fit" of the resultant model.

The project developed a number of prepayment "rate cards" which are confidential to the participating lenders. To demonstrate how these rate cards are used, an illustrative model is shown below in Figure 6. This shows a multiplicative rate card. Either additive or multiplicative models can be developed depending on the situation – there is no intrinsic advantage of either approach over the other.

Figure 6 – Illustrative predictive model



Let us suppose the base prepayment rate for this model is Y% per annum and we want to calculate the prepayment rate for a mortgage drawn down two years ago with a financial incentive to prepay of 2% (i.e. the fixed rate less the current base rate is 2%). From the rate card:

- Drawdown two years ago - time since drawdown level 2 (= 100%)
- 2% financial incentive to prepay - financial incentive to prepay level 3 (=140%)

We then multiply the weights for the parameter levels and the base rate together to calculate the prepayment rate for that mortgage i.e. prepayment rate = Y% x 100% x 140%.

This illustrative model has been simplified considerably – it has only two drivers and the segmentation of those parameters is restricted to four levels. The predictive models used by insurers and the actual models developed during this study are considerably more complex and consequently can generate highly customer specific prepayment rate predictions. Additional features that can be included in these models include:

- Additional parameters – Any number of parameters can be included.

- Additional levels within parameters – The number of levels does not have to be the same for each parameter. Parameters that are more important can therefore be modelled in more detail using more levels.

- Time period specific models – Separate models can be constructed for different time periods to take account of changes in the relationships between drivers and relative importance of drivers at different points in time. For example, the financial incentive to prepay is likely to be more important at the end of the fixed rate period than at the beginning, because it takes time for base rates to move and a significant incentive to arise. Therefore, more levels could be included for that parameter in the latter part of the fixed rate period.

5.2 Quantifying the impact of prepayment behaviour on value creation

As we have discussed earlier, prepayment rates vary according to a number of factors. These include factors relating to the mortgage and external factors, such as interest rates or house price inflation. To understand how prepayments impact value creation, we built a mortgage profitability model that calculates the profit or loss made when a customer prepays. We then used the output from the predictive prepayment rate model as an input to the profitability model. Finally, to allow us to explore the cost of prepayment under various scenarios, we introduced an economic scenario generation model.

5.2.1 Developing the profitability model

We have used an embedded value model – essentially a discounted cashflow model – to quantify the impact of prepayments on value. Profits are projected over the entire future life of the mortgage. In order to model the profitability of products accurately, every feature of the product that may have an impact on value is modelled. Hence, the models used can be quite complex. To deal with this complexity, we start by modelling individual products (e.g. a single mortgage) and add the results up across the whole portfolio. In some cases where a portfolio contains a large number of slightly different products, modelling each mortgage product separately would be time consuming and result in a model that was unmanageable. In these cases, we have used a typical mortgage to represent a number of similar mortgage products[6].

From a business management perspective, it is also interesting to note that embedded value models are structured to look separately at the profitability of the existing book and the profitability of new mortgages. Figure 7 shows some of the information that is required to develop an embedded value model for a mortgage portfolio with an example projection of profits.

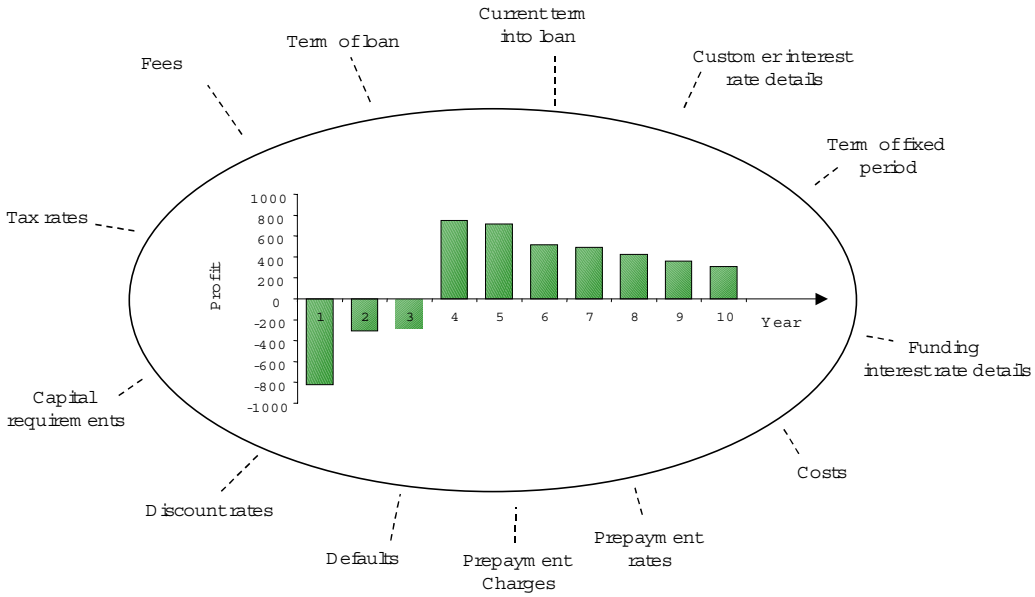


Figure 7 – Inputs for an embedded value mortgage model

5.2.2 Quantifying the impact of prepayments

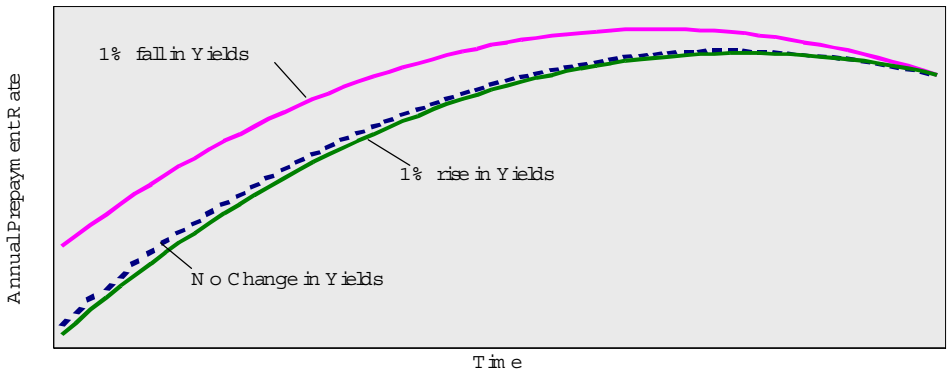
The valuation model developed can be used to assess the probability of prepayment and the cost of prepayment for a single (sample) mortgage or a portfolio of mortgages. We have presented the results for a sample £100m portfolio of new mortgages written on current interest rates for a fixed rate term of 5 years.

Initially, the model was used to analyse the probability of prepayment and cost of prepayment under a small number of economic scenarios. In section 5.3, we also show the range of different costs under different economic scenarios generated by a stochastic interest rate model. As we wanted to investigate the absolute cost of prepayment, no allowance was made in these scenarios for methods to reduce the probability or cost of prepayment (e.g. prepayment charges or funding adjustments as described above). In section 6, we go on to

look at how a variety of risk mitigation techniques can be used to manage prepayment risk exposures.

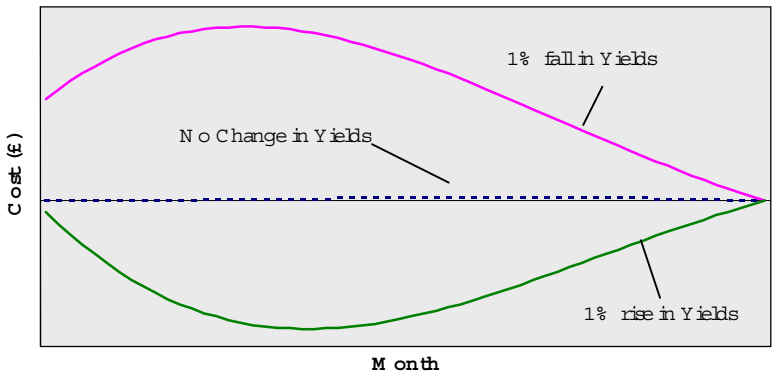
Figure 8, below, shows how prepayment rates may change under different economic scenarios for the sample mortgage. The dotted line shows the prepayment rate if there is no change in interest rates. The top line shows the predicted prepayment rate if interest rates fall by 1%. The prepayment rate rises as this fall in rates creates a financial incentive to prepay. Conversely, a rise in interest rates would reduce the incentive to prepay although some customers will still prepay due to non-financial reasons. These projections can be developed using the output from the rate card analysis described earlier.

Figure 8 – Illustrative changes in prepayment rates under different economic scenarios



The prepayment rates generated in each scenario show how the probability of prepayment changes. We defined the cost of prepayment to be the loss made if the surplus funds were reinvested for the remaining term of the fixed rate period at a variable market rate. For example, if a five year fixed rate mortgage funded at 6% is prepaid after two years and the funds can then only be invested at 5% over the remaining three years, the cost to the lender would be 1% of the prepaid funds per annum for three years. We have calculated this cost as a net present value. Note that the closer to the end of the fixed rate period a prepayment occurs, the less it costs the lender as surplus funds are carried at a loss for a shorter period. By applying this cost to the number of prepayments in each month, it is possible to project the expected monthly cost of prepayment at each point in the life of the mortgage under any chosen economic scenario, as shown in Figure 9.

Figure 9 – Total cost of prepayments occurring in each month



The chart shows the monthly cost of prepayment where interest rates fall immediately by 1%. As we saw above, this fall in interest rates results in an increase in prepayments and the lender loses money when the surplus funds are reinvested at a lower rate. Conversely, an immediate 1% rise in interest rates would result in lower prepayments as there is then a financial disincentive to prepay. However, there will still be some unsystematic prepayments and those funds can be reinvested at a higher rate, making a profit for the lender. The overall effect is that profits due to interest rate rises are smaller than losses from interest rate falls.

The up-front cost of prepayment is the net present value of each of the future monthly costs illustrated above in Figure 9. Table 2 summarises the cost of prepayment for the sample portfolio of new mortgages under various economic scenarios.

Table 2: Cost of Prepayment (% Funds Lent)

Economic scenario	**1% Fall Now**	**2% Fall Now**	**2% Fall in 2 years**
Portfolio (£100m)	0.6%	1.9%	0.7%

An immediate 2% fall in interest rates costs proportionally more than an immediate 1% fall because the increase in interest rates results in a greater (non-linear) increase in prepayment

rates. A fall in interest rates in two years is much less costly because there is less time over which to unwind the funding, and because some of the older business has rolled off the fixed rate before the interest rate fall.

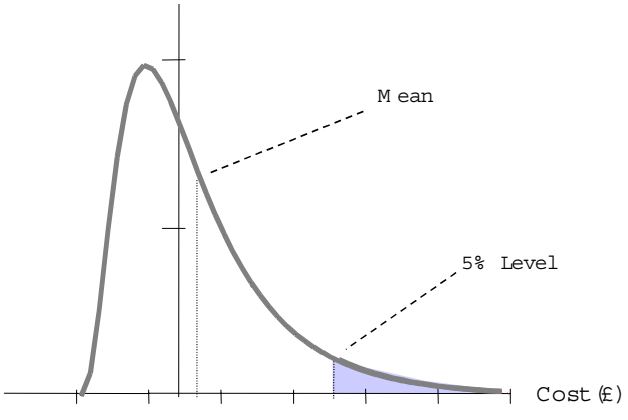
The results thus far have been shown for a new portfolio of mortgages. The same calculations can be performed for an existing book of business. If this book includes mortgages written in the past on historically high interest rates, the cost of prepayment will be higher.

5.3 Quantifying prepayment risk

The analysis thus far has considered specific economic scenarios. Given the uncertainty over future interest rates, a stochastic approach can be valuable. A stochastic interest rate model can be used to generate a whole range of possible economic scenarios. The cost of prepayment can then be measured under each scenario. This will enable the lender to look at the whole range of possible prepayment costs in determining the most appropriate way to manage the risk.

Figure 10 shows a distribution of costs generated by determining the costs for a thousand different interest rate scenarios. The shape of the distribution is interesting in itself, as it is skewed – the mean cost is greater than the median cost. This is because, as demonstrated previously, the cost of an interest rate fall exceeds the profit from an interest rate rise, due to customer behaviour. This analysis can help lenders determine the mean cost of prepayment, or in other words the cost of the prepayment option given to customers. The tail of the distribution also shows how much could be lost in certain extreme scenarios. Using this information, lenders could decide how much capital should be set aside to cover prepayment risk and look at whether other risk management techniques (e.g. buying options to release fixed rate funds early) offer better value.

Figure 10 – Distribution of prepayment costs



As before this analysis has been performed before allowing for any methods the lender is already using to manage the risk, such as prepayment charges or reduced funding. Allowing for this would reduce the cost - i.e. shift the curve to the left. A lender could plot this chart, allowing for the specific features of its mortgages, and then use the results accordingly.

6. DAY TO DAY MANAGEMENT OF THE BUSINESS

The profitability model described in section 5.2 above calculated the cost of prepayment before any preventative risk management strategies had been considered. We now consider how different risk management strategies could reduce the probability and/or cost of prepayment.

In this section, we consider three ways this might be done:

- Through fees or charges to recover (some of) the cost of prepayment risk
- Through proactive adjustment of the funding requirement
- Through identifying those customers and accounts with the highest prepayment risk in order to design products and customer retention initiatives that minimise prepayment risk

6.1 Fees and charges

In this section, we consider fees or charges levied:

- Up-front, to all customers
- At the time of prepayment, to customers who prepay

6.1.1 Charging an up-front fee for the prepayment option

The present value of costs as shown in the section 5.2 represents how much all customers would need to be charged up-front in order to break even in each scenario. In the UK, it is not common practice to make an up-front charge, although in other countries this method is used. However, with pressure on lenders to reduce charges on prepayment, this sort of charging may become more prevalent. An alternative would be to spread the charge over the expected life of the fixed rate mortgage through an increased interest rate. This approach works well to cover the cost of prepayment. It should be noted that having paid up-front for the option to prepay, borrowers might be more inclined to prepay and hence the structure of the charge can affect prepayment behaviour.

6.1.2 Making a charge at the time of prepayment

Another way to reduce the cost of prepayment is to charge customers at the time they prepay. This is a common feature of UK fixed rate mortgages. The approach we have used in this study can assist in the setting of these charges.

As discussed earlier, prepayment charges can be structured in a number of ways. For example, some lenders charge the same proportion of the loan in each year of the mortgage. Others charge a varying proportion. The challenge for lenders is to determine what level and structure of charge will adequately cover potential losses. To investigate this, we looked at a charging structure under which customers who prepay are charged 1% per annum of the original balance for each year of the fix outstanding. As Table 3 shows, for the sample portfolio, a 1% per annum charge neutralises the effect on prepayment behaviour of a 1% interest rate incentive. In fact, the charge results in a small profit in this scenario. However, if interest rates fall further, the lender will make a loss.

Table 3: Impact of 1% p.a. Prepayment Charge (% Funds Lent)

Economic scenario	**1% Fall in interest rates**		**2% Fall in interest rates**	
	No Charge	**1% Charge**	**No Charge**	**1% Charge**
Portfolio (£100m)	0.6%	-0.1%	1.9%	0.6%

It is interesting to note that in addition to helping the lender recoup the costs of prepayment, a charge will also act as a deterrent to prepayment, hence reducing the costs further. In determining the impact of charges on the cost of prepayment, it is important to allow for this behavioural effect. This can make the modelling quite complex. Further study of the impact of charges on prepayment would assist lenders in setting a charge that both mitigates the loss on prepayment but is also acceptable to customers.

6.2 Proactive adjustment of the funding requirement

An alternative risk management strategy is to anticipate that a number of mortgages will prepay each year and reduce the amount of fixed rate funding required accordingly. For example, for a five year fixed rate mortgage, rather than arranging to have all of the funding for the full five years, progressively smaller amounts of funding could be arranged for each successive year. The amount of funding arranged for each year would depend on the lender's

view of expected prepayment rates, taking into account the expected base level of prepayment due to unsystematic prepayments and, potentially, also the likely evolution of interest rates and their impact on expected prepayment rates. The latter could, for example, be based on predictive modelling, similar to that described in section 5.1, validated by stochastic modelling, as described in section 5.3, to understand the distribution of possible outcomes.

Table 4 shows how reducing fixed rate funding required by 6% per annum would impact on the cost of prepayment. We have shown results for two interest rate scenarios – an immediate 1% fall and an immediate 2% fall.

Table 4: Impact of 6% Per Annum Reducing Funding (% Funds Lent)

Economic scenario	**1% Fall in interest rates**		**2% Fall in interest rates**	
	Flat Funding	**Reducing Funding**	**Flat Funding**	**Reducing Funding**
Portfolio (£100m)	0.6%	0.1%	1.9%	0.7%

This shows that under a 1% fall in interest rates, the level of funding we have chosen is such that the cost of prepayment is reduced to close to zero. However, this level of funding is not adequate to reduce fully the cost arising under a 2% fall in interest rates, because the average prepayment rate under this scenario is greater than 6%. The projection model can be run on any number of funding assumptions to assist lenders in determining the appropriate funding level for their business.

Reduced funding can actually lead to higher costs under certain scenarios. For example, if interest rates rise and fewer customers prepay than allowed for in the funding, the lender will have to raise additional funds at a higher rate. This highlights the importance of understanding the range of possible outcomes and the cost and probability of each of these outcomes if this approach is to be adopted.

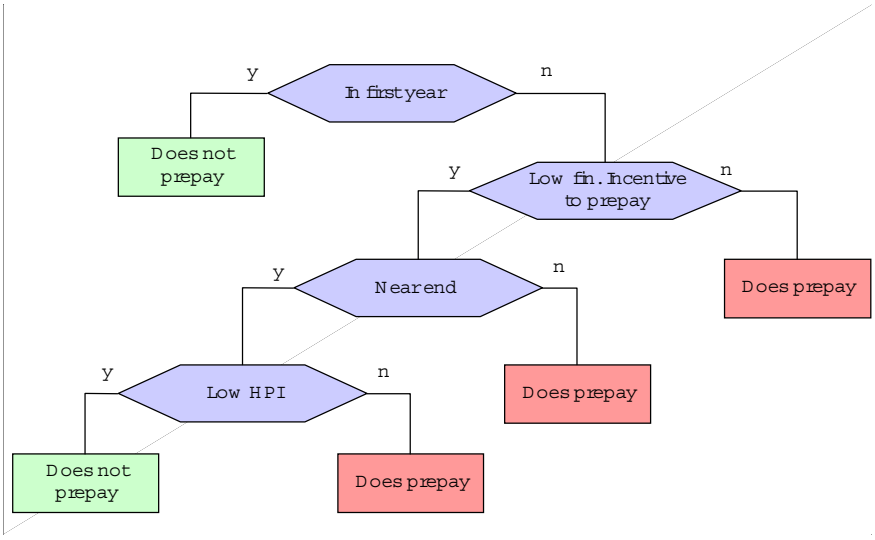
6.3 Customer retention

In Section 2 we noted that empirical evidence shows that not all borrowers exercise their prepayment option rationally and in Section 4 we saw that a number of the suggested drivers of prepayment behaviour are borrower specific. By carefully designing products and

customer retention initiatives, lenders can reduce the probability that existing borrowers will prepay and avoid lending to borrowers who are more likely to prepay. To make this possible, those borrowers who are likely to prepay must be identified. The rate card described in section 5.1 is a powerful technique that helps address this problem, by identifying the probability that a particular customer will prepay their loan. This analysis, coupled with an assessment of the value of that customer to the lender, can be used to develop prepayment risk customer management strategies.

This is not the only technique available to classify customers against a key management objective. In this section we illustrate the use that can be made of decision trees to develop customer management strategies. The objective of this analysis is to develop models that segment the customer base into segments "likely to prepay" and segments "unlikely to prepay". Appropriate customer management strategies can be developed for each customer segment based on this classification.

Figure 11 – A simple customer management decision tree



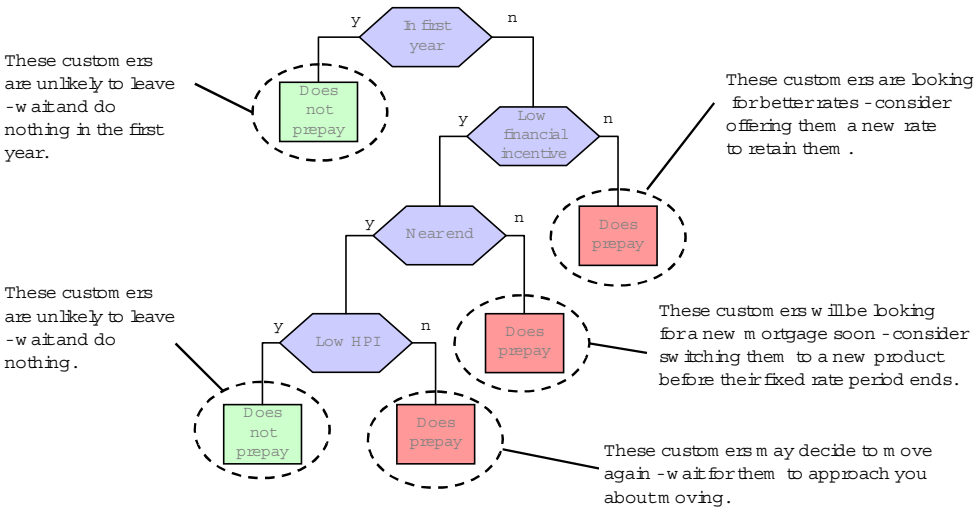
A number of models were developed which are confidential to the participating lenders. However, to illustrate the approach a simplified generic model is shown in Figure 11 above. The tree works by asking a series of questions. In this case, the first question is, "is the loan in its first year?" If the answer is "yes", the left-hand branch is taken and the model classifies those customers as unlikely to prepay. If the answer is "no" the right hand branch is taken and the model asks a further question. The process continues until all customers are

allocated to one of the "terminal boxes" in the model. Note that over time customers can move between terminal boxes, as two of the questions in this example are time based.

Given the above, and assuming that prepayment has a negative financial consequence for the lender, it is relatively straightforward to develop appropriate customer management strategies. Figure 12 illustrates this process. In practice, the decision tree should be linked to a customer valuation model so that retention action is based on an assessment of the value of the customer to the lender.

Note that two of the "terminal boxes" predict "does not prepay" and three predict "does prepay". However, to illustrate the care needed when interpreting these models, consider the definition of the "middle" terminal box – "near end". Given that lenders know that customers often consider moving their mortgage at the end of their fixed rate mortgage, it is likely that this segment is capturing some lender action already in place to retain customers, rather than purely customer initiated prepayment. Further analysis could be used to investigate this phenomenon.

Figure 12 – An example customer management strategy



7. CONCLUSIONS

7.1 The applicability of our techniques

In this report we have identified techniques which can be used to measure, predict and manage mortgage prepayment. In particular, we have shown that:

- Profiling can illustrate how prepayment rates vary for sub-segments of data.
- "Motor insurance style rate cards" can be built to predict prepayment behaviour.
- Projection models can be used to quantify the impact of prepayment on the value added by the business.
- Stochastic modelling techniques can be used to understand the likely range of outcomes.
- The above techniques and models can be used to optimise prepayment risk management strategies, including the use of:
  - Fees and charges
  - Proactive management of the funding requirement
  - Customer retention initiatives

A more widespread use of these techniques has the potential to improve significantly the management of mortgage prepayment risk and we are pleased that several of the participants intend to apply them in their businesses.

Text notes

[1] Liquidity risk is outside the scope of this project.

[2] The incentive to refinance was measured as the difference between the fixed interest rate paid by the borrower and the current Bank of England base rate. In particular, it excludes the financial disincentive of any charges.

[3] At its most severe, negative house price inflation will result in borrowers having negative equity in their property as its value declines, until it is worth less than the mortgage.

[4] Anecdotal evidence suggests that third party advisers, who earn a commission for selling a product, will proactively encourage borrowers to whom they have sold mortgages to prepay if a better deal is available. Indeed, in the US this practice has reportedly become so common that borrowers can leave a standing instruction with their broker to move their mortgage automatically if a better deal is available.

[5]A survey of all the statistical models that could have been used, and their relative merits and demerits, is not within the scope of this study. Readers interested in pursuing alternative methodologies are referred to standard statistical textbooks.

[6] These sample representative mortgages are referred to as "model points". Each model point represents a group of similar actual mortgages. Some judgement is required in grouping the mortgages. There is a balance, however, to be struck between using too many sample mortgages, in which case the model will be unmanageable, or too few, in which case the results may be inaccurate.

The Actuarial Profession is grateful to Tillinghast-Towers Perrin, who conducted the project management analysis and reporting for this study, for their very significant efforts involved in carrying out this project on our behalf.

Tillinghast-Towers Perrin provides management consulting to financial services companies worldwide, and their clients include banks, insurance companies, investment managers and securities firms.