The background of the slide is a photograph of a cityscape. In the foreground, there are several residential buildings with red-tiled roofs and brick chimneys. In the background, there are modern skyscrapers, including a prominent one with a curved facade and a blue-tinted glass exterior. The sky is blue with scattered white clouds.

# Forecasting Dutch Mortgage Prepayments: A Quantitative Model

Q4 2024

## Introduction

Volatile environments call for robust quantitative risk management. Unscheduled repayments of outstanding mortgage principal constitute a substantial interest rate risk for residential mortgage investors. As prepayment risk becomes more relevant in times of increasing interest rate volatility, DMFCO has developed a quantitative model to gain insight into the prepayment behavior of Dutch households. In this whitepaper, we present the methodology and key assumptions used to forecast the future Conditional Prepayment Rate (CPR).

*The CPR is the annualised percentage of the mortgage principal expected to be paid off prematurely*

The CPR model enables the estimation of future prepayment rates under a variety of changing interest rate conditions. The foundation of the model consists of (i) a rate-independent prepayment level based on relocation and mortality rates, combined with (ii) rate sensitive observations of financial markets and mortgagor behavior.

DMFCO recognises prepayment behavior as one of the primary risks within the asset class. Acknowledging its importance, we have developed an empirical model to quantify prepayment risk. This whitepaper aims to provide detailed insight into the CPR model.

Our goal is to equip investors with the tools and knowledge to navigate this risk effectively, thereby enhancing their decision-making capabilities. This whitepaper offers more insight into the background of prepayments, as well as the CPR model.

## A brief recap on prepayment

Prepayment is the right of a mortgage borrower to repay the outstanding principal amount earlier than the regular payment schedule would suggest.

This can happen for several reasons, such as individuals moving, refinancing the mortgage with a new loan, or making additional voluntary payments above the required monthly instalments. In contrast, Dutch borrowers can also transfer their mortgage conditions to their new property when they move house. This is known as porting a mortgage, which we will discuss later in this paper.

Early repayment has significant implications for both borrowers and investors. For example, early repayment can be advantageous for borrowers as it reduces the total interest expenses paid over the lifetime of the loan and shortens the repayment period. In addition, borrowers may exercise this option because they are financially incentivised to do so, for example repaying a mortgage when interest rates decline and subsequently refinancing at a lower rate. This one-sided optionality results in a negative correlation between interest rates and prepayment rates.

Investors are exposed to risks associated with prepayment. Fixed-income securities with prepayment optionality are generally considered riskier for debt investors, as the timing of cash flows is uncertain. When investors receive cash flows earlier (or later) than expected, they may face reinvestment risk (or conversely, opportunity costs), as well as convexity (see annex 3 for more information) in the valuation.

To compensate investors for the uncertainties associated with prepayment, mortgage interest rates in the Netherlands include a prepayment risk premium.

## DMFCO's prepayment model objective

The objective of the prepayment model is to accurately estimate future prepayment rates for residential mortgages. The prepayment assumption is among the most influential parameters in estimating future cash flows, portfolio valuation, and mitigation of interest rate risk. Having a mathematical estimate that minimises the gap between predicted and observed prepayment rates is critical for accurate portfolio valuation, a fair estimation of future returns, and the implementation of effective hedging strategies.

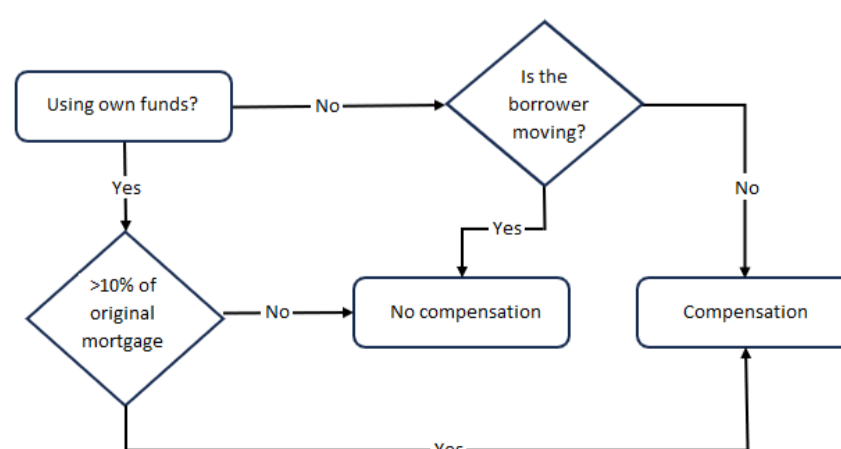
In addition to predictive capacity, the model also aims to enhance transparency in decision-making during the mortgage investment process. By providing a comprehensive understanding of the factors that drive prepayment rates, investors and related stakeholders can evaluate and / or mitigate potential risks associated with fluctuations in prepayment behavior.

## Prepayment compensation explained

Mortgage originators in the Netherlands are financially compensated by borrowers who make early repayments on their loans. This compensation is sometimes referred to as a 'prepayment penalty'.

In accordance with the Mortgage Credit Directive (MCD), lenders can charge borrowers compensation for the costs they incur because of prepayment. The Dutch regulatory body, AFM, has subsequently defined how this compensation should be calculated. Figure 1 provides an overview of situations in which a prepayment penalty is applicable. It is important to note that compensation is only required if the lender incurs a loss, such as when interest rates have fallen.

Figure 1: Schematical overview of prepayment types<sup>1</sup>



<sup>1</sup> At DMFCO borrowers are allowed (contrary to market standards) to prepay more than 10% without a penalty when own funds are used. The impact on the results of this model are however negligible.

In the Netherlands, mortgage borrowers are typically allowed to prepay a fixed percentage annually, usually 10%, of the initial mortgage loan. If the prepayment exceeds this threshold, it may trigger the requirement to pay prepayment compensation. This compensation would only be due if the lender is unable to reinvest the prepaid amount at a similar or higher rate. Therefore, the prepayment compensation is calculated as the present value of the economic loss.

The DMFCO prepayment model aims to capture prepayments that are not covered through prepayment compensation. The rationale behind this approach is that prepayments which are covered by a compensation do not result in an economic loss to investors. The model does not aim to calculate the impact of prepayments on the liquidity profile of a mortgage portfolio, but instead focusses solely on prepayments that affect the portfolio's economic value.

### Methodology

This section provides a comprehensive insight into the building blocks and key drivers of the DMFCO prepayment model. In addition, Annex 2 contains full disclosure of the underlying datasets.

Within the prepayment model, only prepayments whereby no penalty is paid are included. As previously indicated, in case a penalty is paid, there is no impact on the valuation of the mortgage because the investor is compensated for the loss of interest rate income. Prepayment scenarios whereby no penalty is paid include:

- Decease of the borrower;
- Relocation;
- If 10% of the original principal amount is repaid per year (partial prepayment); and
- Specifically for MUNT, if repayments are made in full or in part from the borrower's own resources (i.e. no refinancing).

Research has shown that the main drivers for prepayments are<sup>2</sup>:

- Characteristics of the loan: seasoning, loan amount, mortgage interest rate, penalty conditions, type of property, loan-to-value (LTV);
- Characteristics of the borrower: age, income, creditworthiness, employment status, marital status; and
- Macroeconomics: house prices, mortgage rates, interest rates.

To avoid multicollinearity<sup>3,4</sup>, we omitted several independent variables. After the feature selection process, the following elements remain: seasoning, loan amount, mortgage interest rate, penalty conditions, LTV, age of the

borrower, and mortgage rates (compared to the current market interest rates).

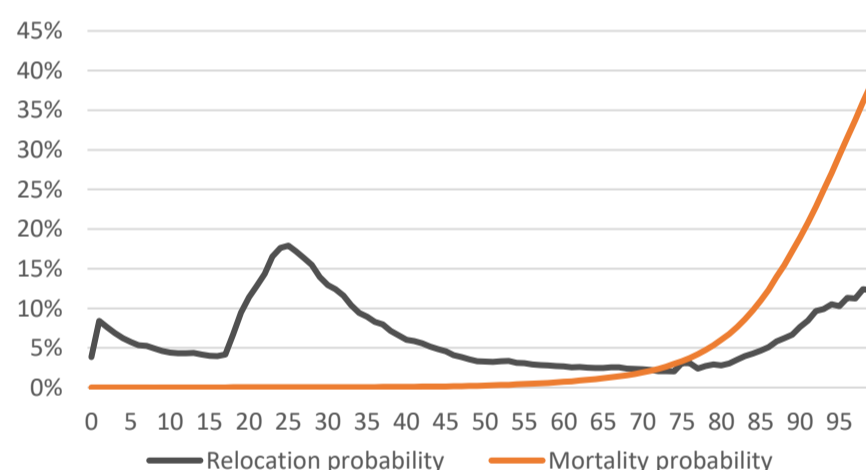
Additionally, house price levels are excluded as the model intends to provide a robust long-term forecast of the prepayment rate. When house prices rise, moving becomes easier, which could (temporarily) lead to higher prepayments; however in the long run this effect should smooth out.

### Blueprint of the prepayment model

Due to the nature of penalty conditions, prepayments in the Netherlands are largely driven by life events such as relocation and death, as the outstanding balance of the mortgage loan is fully repaid in these cases. Therefore, the model begins by considering the mortality probability (Royal Dutch Actuarial Association) and relocation probability<sup>5</sup> (CBS) of a houseowner.

These probabilities, shown in Figure 2, are compounded by the borrower's age cohort. An adjustment is made for cohabitants<sup>6</sup>, to avoid overestimating the prepayment probability.

Figure 2: Probability distribution of relocation and mortality for Dutch mortgage customer per age. (Royal Dutch Actuarial Association & CBS)



It is important to note that the probability of borrowers moving shortly after they have relocated is very low. For this reason, the model uses a glide path based on the age of the loan. In other words, the estimated level of prepayment of a loan is adjusted downward following the disbursement of the loan. Table 1 displays the glide path.

For example, in the first year of a mortgage, the CPR is adjusted downward by 70%. By the end of the 4th year, the CPR is no longer adjusted and fully accounted for in the loan.

Table 1: Overview of prepayment correction based on loan seasonality

Year since mortgage issuance	1	2	3	4	5
Percentage of early repayment probability included	30%	30%	60%	80%	100%

<sup>2</sup> For further detail, see annex 4.

<sup>3</sup> Multicollinearity arises when independent variables in a model are highly correlated, which leads to misleading results.

<sup>4</sup> Younger borrowers in the majority of the cases live in a flat, have a lower mortgage amount with a higher LTV in combination with a lower income and generally a poorer employment status (RIGO, HDN, CBS).

<sup>5</sup> Based on the moving behaviour in 2022

<sup>6</sup> Household projection 2021-2070: Household growth continues (CBS)

This path is based on the historical figures of the MUNT portfolio.

After determining the expected prepayments resulting from death and relocation, we add partial repayments to the expected prepayments<sup>7</sup>. Historically, this level has hovered around 1%. Although the level of partial repayments is correlated with interest rates, this fluctuation is negligible compared to the variation in full repayments and their consequent impact. Therefore, the volatility of partial repayments is ignored, and a long-term average is used as a proxy to address this effect on overall prepayment. This approach is consistent with research from Rabobank<sup>8</sup>.

### Porting option ('meeneemregeling')

Mortgage borrowers are allowed to port their mortgage conditions when relocating to (and wanting to finance) a new property. This is economically attractive if the interest rate on the mortgage loan is lower than the mortgage rate at the time of relocation. To determine whether it is advantageous to exercise the porting option, the interest rate of the mortgage is compared with the risk-free forward interest rate<sup>9</sup>, increased by the actual mortgage spread. The forward curve is used because it is considered the best (albeit imperfect) estimate of future interest rates<sup>10</sup>.

In some cases, however, borrowers are not able to exercise the porting option. For example, when two separate borrowers decide to live together<sup>11</sup>, or if the borrower does not meet the lender's underwriting criteria. Although the latter cases are difficult to predict, data on the number of people who will live together is available from CBS.

The inclusion of the porting option varies by age category due to the factors mentioned before:

- For individuals over the age of 65, the probability of moving house to live together is set at zero. When such individuals move, it is assumed that they will fully port their existing mortgage conditions. In the event of death, the mortgage is fully repaid;
- For people under the age of 65, the probability of moving house to live together is estimated at 39% for people aged 35 or younger and 18% for individuals between the ages of 35 and 65 (CBS). In other words, for someone under 35, it is assumed that 39% of the time, 50% of the porting option is used. For the remaining 61%, it is assumed that the entire mortgage will use the porting option, provided that this option is in-the-money; and

- The porting option is considered worthless if a mortgage has a fixed rate period of less than one year or an LTV of less than 25%. This adjustment is made because it is of limited economic value to exercise the porting option.

Further assumptions of the CPR model are demonstrated in Annex 1 of this document.

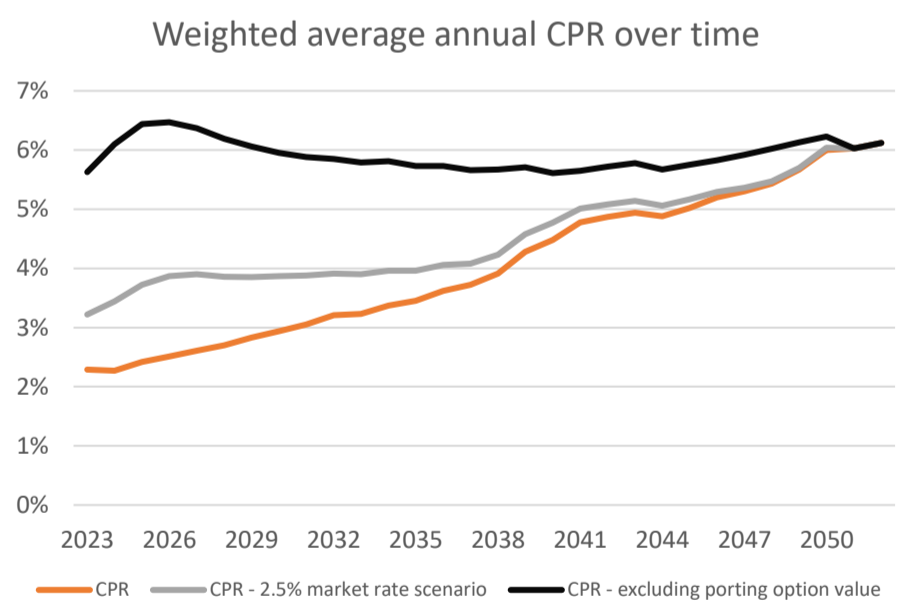
### Results DMFCO's prepayment model

This section presents the results of the DMFCO prepayment model based on three different scenarios. These scenarios examine the impact of the porting option and interest rate developments. The simulation is performed under the market conditions and demographic characteristics of Q4-2023 and uses the DMFCO mortgage portfolio to calculate the expected CPR. The DMFCO mortgage portfolio was originated in the past 10 years and therewith is reflective of an average mortgage portfolio in the Netherlands.

### Prepayment excluding porting option value

If the impact of the porting option on prepayment levels is ignored, the prepayment model forecasts a CPR of around 5-6% in the long run. This is also in line with the historical levels we have observed in the MUNT portfolio and the overall mortgage market<sup>12</sup>. The black line in Figure 3 shows a forecast of the weighted annual CPR levels, excluding porting option value, for the next 30 years.

Figure 3: Results of the prepayment model under three different scenarios



<sup>7</sup> Mainly driven by financial windfalls such as yearly bonuses, tax refunds, or inheritance.

<sup>8</sup> CPR research Rabobank.

<sup>9</sup> Zero 6-month curve.

<sup>10</sup> The advantage of this method is that it is completely objective, transparent and easy to interpret. The disadvantage is that it assumes market efficiency and forward rates have limited predictive power.

<sup>11</sup> Because not both cohabitants can take their mortgage with them, hence a choice has to be made. Only in the rare situation that both cohabitants have a mortgage with the same lender, both mortgages could potentially be ported.

<sup>12</sup> CPR research Rabobank.

<sup>13</sup> Interest Rates Likely to Return Toward Pre-Pandemic Levels When Inflation is Tamed (IMF)

### Prepayment in a 2.5% interest rate scenario – including porting option

We also examined the effect of a different interest rate environment on the expected CPR. Current interest rates are relatively high compared to those in the past 20 years, and inflation expectations remain at elevated levels. Despite the forward curve being the best proxy for future market conditions, the IMF anticipates the following regarding inflation<sup>13</sup>:

*“Overall, our analysis suggests that recent increases in real interest rates are likely to be temporary. When inflation is brought back under control, advanced economies’ central banks are likely to ease monetary policy and bring real interest rates back towards pre-pandemic levels. How close to those levels will depend on whether alternative scenarios involving persistently higher government debt and deficits, or financial fragmentation materialise.”*

We modeled this scenario by assuming a constant 2.5%<sup>14</sup> interest rate environment. This brings the weighted average long-term CPR to a level of 4.3%. The development of the CPR-rates under this scenario is depicted by the grey line in Figure 3.

### Discussion

All scenarios converge towards a long-term CPR of 5%-6%. The gap between initial prepayment forecasts of the model with and without the porting option is interesting to observe: it shows how significant the porting option value is in a volatile interest rate environment. The gap remains significant even when a constant 2.5% interest rates is applied.

Scenarios which consider the option value of porting, show an increasing prepayment trend over time. This is mainly due to the shape of the forward curve (currently inverted), combined with the seasoning effect of existing mortgages and an aging population. As a result, expected CPR levels are projected to rise over time.

### Conclusion

The CPR assumption is amongst the most influential parameters in estimating future mortgage cash flows, portfolio valuation, and managing interest rate risk. Prepayment behavior has dramatically changed in recent years, mainly due to borrowers exercising the porting option in their mortgage.

The intrinsic value of the porting option has become in-the-money for many borrowers due to rising interest rates. This trend has led to a sharp decline in prepayment rates.

DMFCO has developed a quantitative prepayment model to estimate expected early repayments whereby borrowers do not pay compensation. The model is based on high-quality data sources such as the CBS, the Royal Dutch Actuarial Association, and the underlying MUNT portfolio. It provides robust forecasts under various scenarios that reflect different market conditions.

Given current market conditions and demographic characteristics, the prepayment model estimates a weighted average CPR of 3.6% over the estimation horizon. The prepayment trend is however upward sloping over time, converging towards 5-6% levels in the long term. This upward trend is primarily due to the diminishing optionality value of porting over time.

<sup>14</sup> This is based on a long term inflation level of 2% and a growth rate of 0,5%.

## Annex 1: Model assumptions

DMFCO has consciously decided to make specific assumptions in drafting the model. An overview of those choices is provided below:

- No technical analysis is performed, meaning that recent prepayments are not used to make short-term forecasts. This technique is used by some parties, after which the prepayments tend towards a long-term average. Because interest rates follow a random path, we have opted for a bottom-up analysis that does not take into account short-term market situations.
- The consequences of economic cycles are not considered, as they are difficult to predict and tend to average out in the long run.
- While partial prepayments do fluctuate over time, for example due to changes in interest rates, the impact of these fluctuations is so limited that they have not been taken into account.
- In the event of death, it is unusual for both partners to die simultaneously. However, it is very complex to take this effect into account. Additionally, death primarily influences the CPR if the borrower is already at an advanced age and a surviving partner also has a low life expectancy. The impact of this assumption is expected to be limited.
- The effects of bridge loans are not included, as their effect is very limited. Bridge loans typically have a variable interest rate that are valued close to nominal value, posing little interest rate risk. Seasonal effects (e.g., more redemptions in December) are not included because their effects add limited value to the model in the long term.
- Differences between repayment types (annuity or interest-only) are considered limited and because borrowers often also combine repayment types, this effect is not included.
- This model uses a relocation probability based on 2022 data. In a next version of this model, we will explore whether using a 10-year average might provide more stability to the model. For now, we consider the impact to be limited on the basis of historical data from the Dutch Statistics Office (CBS).

## Annex 2: Deepdive in used data sets

This annex provides a brief summary of the key data sets of the DMFCO prepayment model, along with their implication and sources.

Overall, the data sets can be divided into three different categories, as shown in Figure 4.

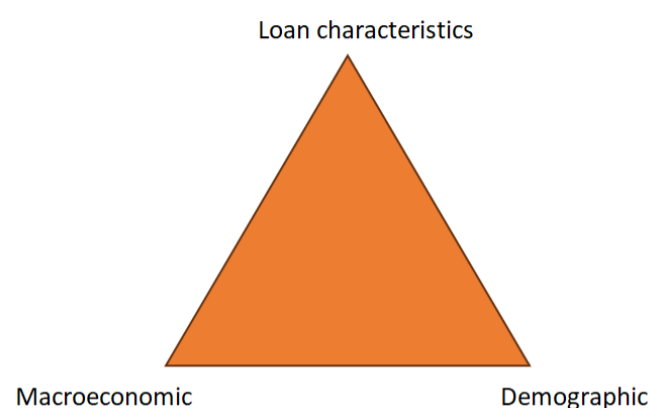


Figure 4: Visual overview of input data categories of the prepayment model.

### Loan characteristics

#### DMFCO mortgage portfolio

Over 180,000 unique Dutch individuals have a MUNT mortgage for their homes. **DMFCO** automates the collection, processing, and routing of information from both individuals and their property. The data set contains hundreds of valuable data points per mortgage, with the most important predictors being the borrower's age, mortgage rate, age of the loan, loan amount, and LTV.

### Demographic

#### Relocation probabilities

The outstanding balance is fully repaid at the moment that a borrower moves houses. Therefore, relocation probabilities have a significant impact on expected prepayment rates. **Statistics Netherlands (CBS)** publishes monthly relocation data by age group in the Netherlands via their API-connection and website<sup>15</sup>. Combining this data with the Dutch population figures per age<sup>16</sup> provides insight into the relocation probabilities. This enables us to estimate a relocation probability specific for each borrower.

#### Mortality projections

Mortality also results in the full repayment of the remaining principal, which makes mortality a fundamental element of the prepayment estimation. The **Royal Dutch Actuarial Association** publishes a projection table for Dutch life expectancy every two years.<sup>17</sup> These current and future mortality rates are integrated into the DMFCO mortgage portfolio to construct an expected probability of death each simulation year.

<sup>15</sup> Relocation data by individual characteristics in the Netherlands ([CBS](#))

<sup>16</sup> Dutch population figures per age ([CBS](#))

<sup>17</sup> Morality Projections ([The Royal Dutch Actuarial Association](#))

### Cohabitation

The prepayment model focuses on loans that are repaid. Since CBS provides relocation statistics based on the number of moving people rather than moving households, a correction is made for cohabitants to avoid double counting. The **CBS** publishes annual data about household composition across the Netherlands.<sup>18</sup>

### **Macroeconomic**

#### Forward swap rate

As a proxy for risk-free interest rates, we use the 6-month EURIBOR zero swap rate. The interest rate curve is obtained with tenors as far as 30 years, and is linearly interpolated between liquid points. Combined with the mortgage spread, this allows us to estimate the option value of the interest on the mortgage. The forward swap interest rate curve is obtained via **Refinitiv**. While this data is not publicly available, as Refinitiv is a paid data provider, other proxies for risk-free rates are freely available online.

#### Mortgage spread

As a proxy for the interest rate spread, we use the weighted average portfolio spread of the **DMFCO valuation**. The results of the valuation, amongst which spreads, performance attribution, and sensitivity analysis, are available for DMFCO investors in the monthly Valuation Report.

### **Annex 3: Impact on the valuation of mortgages loans: Convexity**

Convexity is a sensitivity measure used in mortgage valuation to assess the impact of changes in interest rates. Negative convexity arises due to the embedded prepayment option in mortgage loans. This leads to higher volatility in valuations as a result of interest rate fluctuations. This effect amplifies price declines in rising interest rate environments and dampens price appreciation in falling interest rate environments.

Figure 5 illustrates the concept of convexity<sup>19</sup>.

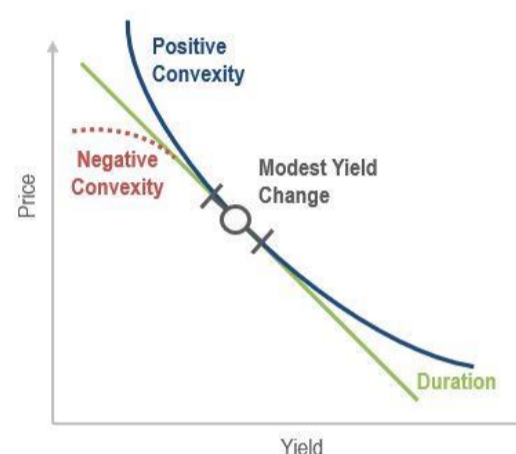


Figure 5: Visual representation of convexity

The strong prepayment compensation mechanism of Dutch residential mortgages helps counteract negative convexity, reducing financial risk exposure.

<sup>18</sup> Cohabitation data in the Netherlands ([CBS](#))

<sup>19</sup> The Trick or Treat of Bond Convexity ([Income Research](#))

#### Annex 4: Delving further into prepayment drivers

This section explores existing research on prepayment behavior in residential mortgages, as well as the unique aspects of the Dutch housing market.

While no model can fully explain all the reasons for prepayments, the four most common drivers of prepayment were first established as early as 1985. The Real Estate Economics Journal identified the following contributing predictors: refinancing incentive, path dependency, seasonality, and seasoning.

By designating these variables into relevant measurable components, the main drivers for Dutch residential mortgage prepayments are identified as:

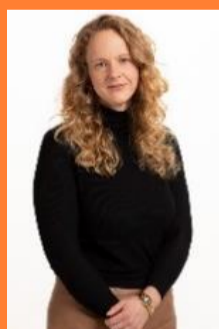
- Characteristics of the loan: age of the loan, loan amount, mortgage interest rate, penalty conditions, type of property, LTV;
- Characteristics of the borrower: age, income, creditworthiness, employment status, marital status;
- Macroeconomic: house prices, mortgage rates, interest rates.

Although a wide variety of research is available on this topic, most studies are based on research from the United State (US). In the US, unlike in the Netherlands, there are no statutory prepayment penalties. There is no premium burden for the borrower's incentive to prepay the mortgage, which makes US prepayment activity highly sensitive to long-term interest rate changes. Given the path-dependent characteristics of prepayment behavior, the cash flow predictions become much more uncertain.

Mortgage lenders across Europe typically penalise prepayment based on a fixed threshold of the amount that is repaid ahead of contract. Although the European Union does not oppose a standardised approach, most European countries base prepayment compensation on the amount that is repaid. The use of fixed thresholds, such as in Belgium, introduces significant optionality into observed prepayment rates.

“market interest rate linkage” mechanism. The compensation amount depends on the market interest rate. This approach is considered distinctive because it establishes a direct link between the cost of early repayment and the interest differential incurred by the lender as a result of the early return of the mortgage capital. Consequently, this may result in substantial penalties, particularly during periods of declining interest rates when lenders face the prospect of re-lending funds at lower rates and thus suffering financial losses from early repayments. Early repayments in Germany are structured in a similar way.

Despite the fundamentally different market compensation structure between the Netherlands and the United States, much of the Dutch academic literature draws on studies and findings from the US. The current literature on prepayment rates in the Netherlands consistently shows that the financial behaviour of Dutch households, especially regarding prepayment, is not always rational<sup>25</sup>. While insights from the US may provide valuable theoretical frameworks and methodologies, the unique regulatory environment, institutional arrangements, and borrower behavior inherent in the Dutch mortgage landscape warrant a more nuanced and contextually grounded approach to research on mortgage prepayments in the Netherlands.



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