

Louvain School of Management

**Which mortgage option – fixed or floating
interest rates – offers greater financial benefits
to Belgian private mortgage borrowers ?**

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Abstract

This thesis investigates the cost effects of fixed and floating interest rate mortgages to Belgian private borrowers. Using historical data, simulation techniques, and stochastic interest rate models, we compare the total discounted cost of various mortgage structures. The analysis includes fixed-rate mortgages based on data from the broker *Immotheke*, *Finotheke*, 10-year OLO yields, and swap rates, as well as floating-rate mortgages with reset frequencies 1/1/1, 3/3/3, and 5/5/5. Results indicate that floating-rate mortgages, particularly the 1/1/1 type, are generally more cost-effective in a declining or stable interest rate environment, but at the cost of instability in monthly payments. Fixed-rate options, while offering greater stability, tend to result in higher overall costs. Refinancing opportunities were also examined, and the results indicate that profitability depends on the volatility of the data used. Finally, simulations based on the Vasicek model also confirm the relative advantage of floating rates in most cases. These findings emphasize the importance of the borrower risk tolerance, interest rate expectations, and loan characteristics when choosing a mortgage structure.

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1 Introduction

The decision between choosing a fixed or a floating interest rate on a mortgage is one that private borrowers in Belgium face when financing property purchases. This decision is critical regarding the long-term financial implications on the part of the borrower when conditions and trends in the economy and interest rates constantly change.

Fixed mortgage rates have the advantage of stable payments throughout the life of the loan and prove to be more attractive in cases of low or stable interest and market rates. In contrast, floating mortgage rates fluctuate with the market. In fact, borrowers can potentially benefit from lower payments in the short term but be exposed to the risk of rate hikes in the future. Given Belgium's historically volatile interest rate environment, understanding which mortgage option offers better financial outcomes for borrowers is timely and relevant.

This kind of study could, therefore, be helpful for practitioners, such as financial advisors and mortgage lenders. Indeed, it can provide them with specific evidence on how to guide clients in making the best decisions. For the researchers, the study contributes to a broader discussion on consumer decision-making under economic uncertainty, especially in the context of the housing market.

These considerations lead to the following research question : “ Which mortgage option - fixed or floating interest rates - offers greater financial advantages to Belgian private mortgage borrowers? ”

The most important theoretical inputs we are going to use in this report are the fixed and floating interest rate models in the case of a mortgage. In addition to these models, it is crucial to consider interest rate risk management techniques, particularly for the floating rate model. This includes setting caps on how much the rate can fluctuate, providing a level of protection for borrowers against big increases in interest rates. These conditions help balance the potential short-term gains of lower initial payments with the long-term risk of rising rates. Furthermore, the present value of cash flows concept plays a crucial role in comparing fixed and floating interest rate mortgages. By actualizing cash flows, we will be able to accurately assess the long-term cost of each mortgage option, taking into account the time value of money.

Concerning the overview of this master's thesis, the first part will consist of the literature review. This will include the examination of existing research on mortgage rate choices and borrower decision-making. After, we will explain the methodology used to gather and

analyse the data before diving into the presentation of the findings. This research paper will continue with a discussion about the implications of the results for Belgian private borrowers. To conclude this thesis, we will summarize the key findings and provide some recommendations for future research.

2 Literature Review

2.1 Introduction

During the second part of 2024, over 47,000 mortgage loans were granted in Belgium. This represents a total of approximately €7.7 billion and an annual growth of 5.8% in credit volume (Febelfin, 2024). Belgian's current mortgage market is dominated by fixed-rate loans. Indeed, "96% of borrowers in Belgium have opted for fixed rates, marking the highest level in over a decade. This preference indicates a tendency among Belgians to prioritize security and predictability in their mortgage payments amidst economic uncertainties." (Roisin, 2024). In this regard, Belgium holds a unique position in Europe (Febelfin, 2024). In other countries such as Germany and the Netherlands, we observed the opposite trend, a decline in fixed-rate mortgages (Roisin, 2024). *The Belgian Mortgage Market in a European Perspective* article, which analysed trends in the Belgian mortgage market between 1999 and 2007, already reported the domination of fixed-rate loans (Zachary, 2009). These conservative lending practices protected the market against the worst effects of the financial crisis. Indeed, it contributes to the stability of the Belgian housing market (Febelfin, 2024). However, other European countries suffered more from the crisis due to their preference for variable-rate loans (Zachary, 2009).

In their paper, *The Myopic Choice Between Fixed and Adjustable Rate Mortgages in Flanders*, Damen and Buyst (2013) raised the following fact: "From 2003 to 2012, the Belgian share of mortgages with an initial rate fixation period up to one year fell from 62% in 2004 to 8% in 2006, recovered to 58% in 2010, and fell again to 5% in 2012." Nowadays, the presence of variable-rate mortgages stays low. In fact, in 2024, the interest rates were supposed to stay stable, leading to predictable lending conditions that encourage fixed mortgages (Roisin, 2024). As predicted, in the second quarter of 2024, fixed-rate loans were overwhelmingly preferred, offering stability (Febelfin, 2024). And once again, the contrast with broader European trends, underlining local preferences for security in uncertain times is observed (Roisin, 2024).

2.2 Theoretical Framework

Understanding the definitions and mechanisms of fixed vs floating interest rate mortgages is critical when choosing between them. Fixed-rate mortgage (FRM) is a type of mortgage in which the borrower pays a fixed interest rate and a fixed monthly payment over the

life of a loan (ING, 2021). Predictability makes it easier to plan and is generally more desirable in times of economic turbulence or when interest rates are expected to rise. This contrasts with an adjustable-rate mortgage (ARM), whose interest rate is periodically reset in line with a benchmark, such as a market index. In our case, this market index is calculated based on the prices of Belgian government bonds. These values can change relatively quickly, as can the interest rate of the mortgage loan (Guide-épargne, n. d.). Certainly, these adjustments make borrowers vulnerable to higher payments if rates rise but could provide short-term savings if rates fall.

Belgium maintains stability by imposing caps on how much ARMs can be adjusted during the duration of the loan, offering more predictability to borrowers (Kau et al., 1993). Caps are financial products that protect the client against high interest rate increases. The cap value is generally 2, 3, 4, or 5% and could not, in any case, be higher than the initial interest rate of the loan. We can easily deduct that a rate with cap 5 will be higher than another one with cap 2 (Le CAP / le FLOOR, n. d.).

Two theoretical concepts form the basis for fixed versus floating rate decisions: the *Time Value of Money*, and *Risk Management*. The *Time Value of Money* indicates that a euro today is more valuable than a euro in the future because of its earning potential. This is a relevant concept in mortgage decisions because the borrower must weigh the present value of future payments (Reynalda & Barri, 2024). Below is a formula used to bring future payment into present value using interest rate (Reynalda & Barri, 2024).

$$PV = \sum_{t=1}^n \frac{C_t}{(1 + r)^t}$$

where

- PV: Present value of cash flows
- C_t : Cash flow at time t
- r: Discount rate
- t: Time period
- n: Total number of payments

Fixed-rate mortgages typically have higher initial costs but offer some security against rising interest rates in the future, consistent with the time value of money principle of cost predictability (ING, 2021).

In mortgage choice, another important factor is *Risk Management*. Fixed-rate mortgages are for the risk-averse. These are the types of borrowers that value stability and the ability to budget accurately over a long horizon (ING, 2021). This means these borrowers are now protected from potential financial tension in the future with rising interest rates (KBC Brussels, n. d.). Floating-rate mortgages are more suitable for borrowers with a higher risk tolerance or for those who expect falling interest rates. These borrowers enjoy lower initial payments, but are uncertain as payments may increase during the loan term (ING, 2021).

These definitions and theoretical concepts provide a foundation on which fixed and floating mortgage rates could be assessed in terms of their financial implications. They highlight how factors such as stability, cost predictability, and risk tolerance influence borrower preferences.

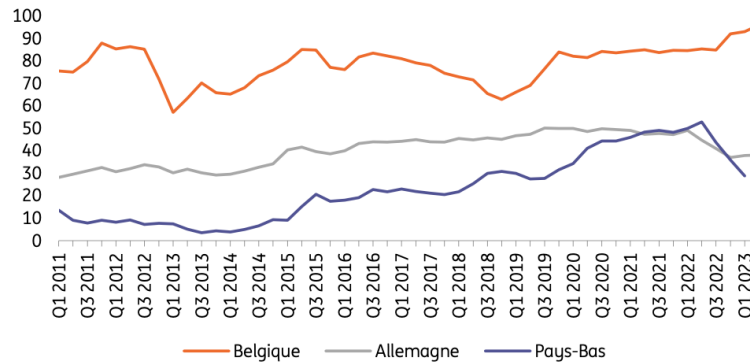
2.3 Mortgage Market Dynamics

The dynamics of interest rates in the Belgian mortgage market are predetermined by macroeconomic factors, particularly the European Central Bank (ECB) policies. "The interest rate you agree with the bank is largely determined by the interest rates set by the European Central Bank." (ING, 2021). The ECB's monetary policy decisions, such as adjusting the interest rates, stimulate economic growth, directly affecting mortgage interest rates (ING, 2021). For example, during slow economic times, the ECB can cut interest rates to ensure more borrowing and investment. This creates a favorable environment for borrowers, particularly for those opting for variable-rate mortgages.

Inflation volatility plays a significant role in setting mortgage rate trends. Inflation volatility refers to how much inflation rates fluctuate over time (Albertazzi et al., 2024). Lower volatility indicates a stable inflation environment. In countries with high inflation volatility, ARMs are more common because borrowers prefer the flexibility of rates moving downwards in case of stabilization or decline of inflation (Albertazzi et al., 2024). In Belgium, borrowers tend to choose fixed-rate mortgages as the rates remain relatively stable (Ridole, 2024).

Indeed, the proportion of Belgian borrowers choosing a fixed-rate mortgage has continued to grow during the year 2023. "According to the latest data from the European Mortgage Federation (EMF), the proportion of Belgians opting for a fixed-rate mortgage has reached its highest level in more than 10 years." (Thierie, 2024). This is a consequence of the rise in interest rates in previous years, which encourages borrowers to avoid taking any risks.

However, in countries such as the Netherlands and Germany, more and more people are willing to take this risk, as they anticipate a downward in interest rates in the coming years. These opposite trends can be observed on the figure below.



Source: EMF

Figure 1: Share of fixed-rate mortgages with a term of more than 10 years.

Recently, floating rates have increased faster than the fixed ones. According to the National Bank, in October 2023, the floating rate had a value of 5.4% while the average fixed rate was 3.5% (Thierie, 2024). The variable rate was therefore much more expensive at the start, and it would need to drop significantly to become more advantageous than the fixed rate. That is why most Belgian borrowers opted for the "more interesting" fixed rate. "Furthermore, our ING survey shows that most Belgians (51%) fear that loans will become even more expensive in 2024." (Thierie, 2024). For sure, this result will not help to increase the proportion of floating-rate mortgages in Belgium.

Financial literacy is defined as the "knowledge and understanding of financial concepts and risks, and the skills, motivation, and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life." (Vidermanova & Melusova, 2015). This concept might prove to be an influential variable in shaping household decision to take on mortgage debt. "Financial literacy in mortgage concepts enables homeowners to make better financial decisions, plan effectively, and evaluate repayment strategies." (Reynalda & Barri, 2024).

It is arguable that, in countries with limited levels of financial literacy, borrowers often lack the necessary knowledge to evaluate the risks and benefits associated with adjustable-rate mortgages (ARMs). As a result, such borrowers prefer fixed-rate mortgages (FRMs), which reduce decision-making complexity. As an example, the research paper by Damen

and Buyst (2013) in Flanders shows the following result: “Households make mortgage decisions based on initial payments rather than long-term financial risks, suggesting a short-sighted (myopic) approach (Damen & Buyst, 2013). Financially literate borrowers are better positioned to evaluate any potential cost savings from ARMs, as well as appreciate and manage the risks of the loan (Albertazzi et al., 2024). Thus, in economic contexts where rates are expected to remain stable or decrease, these borrowers will be more likely to opt for ARMs. This relationship underscores how financial education makes borrowers capable of making informed decisions about mortgage opportunities.

2.4 Role of Financial Instruments

Mortgage-backed securities (MBS) are financial securities created by pooling mortgages together and selling them to investors. The process transfers risks from lenders to investors, thereby enabling banks to provide fixed-rate mortgages (FRMs) without bearing the long-term interest rate risks. By securitizing FRMs, lenders are free from these risks and hence are able to confidently continue originating FRMs. A robust MBS market further encourages this practice, as it provides liquidity and simplifies risk management for banks.

Covered bonds are debt securities covered by high-quality loans such as mortgages. However, unlike MBS, they remain on the balance sheet of the issuing bank. That means the bank still bears the responsibility for paying back bondholders if the loans default. Covered bonds usually have long maturities and fixed interest rates, which closely correspond to the characteristics of FRMs. Banks use the proceeds of these bonds to fund FRMs and therefore have a stable and reliable funding source.

In countries where the covered bond market is well developed, the creation of a predictable funding environment through covered bonds encourages banks to offer FRMs (Albertazzi et al., 2024). In fact, these bonds became a significant funding instrument throughout Europe. Indeed, Germany, Spain, and France are the largest covered bond markets (Zachary, 2009). In Belgium, banks are still heavily reliant on traditional deposits but are increasingly using market-based funding methods. However, in that country, the use of such instruments has been slower due to the absence of specific legislation (Zachary, 2009).

2.5 The Refinancing Process

One of the key features of the Belgian market is the strong protection granted to households thanks to the large number of mortgage loans granted at fixed interest rates over longer periods. Moreover, in the case of refinancing, the Belgian market already offers the most advantageous early repayment compensation for consumers in Europe, with a maximum penalty equivalent to 3 months of interest (Febelfin, 2024).

In fact, when borrowers choose a fixed rate mortgage, the rate remains fixed throughout the mortgage period. However, in Belgium, when interest rates drop, they can benefit from it by the refinancing process. This allows borrowers to reduce their monthly payments or overall interest cost.

There are two main refinancing methods. First, borrowers can choose to refinance internally and renegotiate the interest rate directly with their current bank. This process is the fastest one and includes a lower cost, especially since the new law which forces banks to opt for a modification of the mortgage loan rather than entering into a new credit agreement (Suy, 2024). In fact, since June 2024, banks cannot charge early repayment penalties, equivalent to three months of interest. In addition, banks can now only charge administrative fees up to €175 maximum (Ridole, 2024). This new legislation, led by former Economy Minister Pierre-Yves Dermagne (PS), aims to reduce the costs charged by banks when refinancing a mortgage. However, banks are not legally obliged to accept the renegotiation and may refuse if they perceive a loss in profitability.

The other option is external refinancing. The borrower repays the original loan and a new loan is signed with another bank at a lower interest rate. In that case, notary fees, mortgage registration fees, and new loan set-up cost apply. The three-month interest penalty must also be paid by the borrower (Febelfin, 2024). External refinancing is therefore more expensive than the previous option.

According to John Romain, founder of Immotheker Finotheker, refinancing is only worthwhile under certain conditions. The difference between the old and new rates should be at least 1%, and there should be at least 10 years remaining on the loan, because refinancing is not free and generates a variety of costs (Ridole, 2024).

2.6 Computations

2.6.1 The Monthly Payment

To compute the monthly mortgage payment, we use an annuity formula that accounts for the loan amount, interest rate, and loan term to determine a fixed monthly payment. For a fixed-rate mortgage, the following formula ensures that each monthly payment remains constant while the proportion of interest and principal changes over time (Reynalda & Barri, 2024).

$$PMT = \frac{P \times r \times (1 + r)^n}{(1 + r)^n - 1}$$

where

- PMT: Monthly payment
- P: Loan amount (Principal)
- r: Monthly interest rate
- n: Total number of payments (Loan term in years * 12)

2.6.2 The Amortization Process

The concept of amortization explains how loan payments are divided to pay interest and principal over time, showing how the interest portion decreases as the loan balance is reduced. This process allows borrowers to understand how their loan balance decreases over time while meeting their repayment obligations (Reynalda & Barri, 2024).

Each monthly payment consists of:

1. Interest Payment: The portion of the payment allocated to the interest on the outstanding loan balance.
2. Principal Payment: The portion that reduces the remaining loan amount.

At the start of the loan, a larger share of the payment is allocated to interest, as the outstanding balance is higher. Over time, as the principal reduces, the interest portion of

the payment decreases, and a larger portion is applied toward the principal (Reynalda & Barri, 2024).

Therefore, we use the following formula:

$$\text{Interest Payment} = \text{Remaining Loan Balance} \times \text{Monthly Interest Rate}$$

$$\text{Principal Payment} = \text{Monthly Payment} - \text{Interest Payment}$$

$$\text{Remaining Loan Balance} = \text{Previous Loan Balance} - \text{Principal Payment}$$

2.7 Conclusion

This literature review covers the important variables influencing the decision between fixed-rate mortgages (FRMs) and adjustable-rate mortgages (ARMs) in Belgium. It shows the dominance of FRMs, induced by the preference for stability by the borrowers during economic uncertainties. Macroeconomic factors such as the European Central Bank's policies and volatility in inflation also impact the mortgage market. Additionally, financial literacy also plays an important role, with more informed borrowers better equipped to navigate the complexities of ARMs. Furthermore, financial instruments such as mortgage-backed securities and covered bonds increase the availability and, therefore, the affordability of FRMs, making them more attractive in the market.

Building on these insights, this thesis will quantitatively assess the financial implications of both mortgage options. Using 20 years of data and simulating 10-year mortgages at fixed and variable interest rates, the study will evaluate the cost-effectiveness of each option. By combining a theoretical analysis with empirical modeling, we aim to answer the research question: “ Which mortgage option - fixed or floating interest rates - offers greater financial advantages for Belgian private mortgage borrowers? ” This approach will provide a data-driven perspective to complement the conceptual findings, offering valuable insights for borrowers, lenders, and policymakers.

3 Methodology

This section outlines the methodology used to assess the financial performance of fixed and floating-rate mortgages. The objective is to compare the total amount paid by a borrower under different loan structures: fixed-rate mortgages and three types of variable-rate mortgages (1/1/1, 3/3/3, and 5/5/5), all with a 10-year repayment horizon. In order to obtain fixed rates, three different methods have been used: the fixed rates from the broker *Immotheke Finotheker*, the OLO 10-year yields, and the swap rates.

3.1 Data Collection

Several data sets were required to begin the analysis.

Firstly, historical monthly reference indices for private mortgage loans in Belgium were downloaded, covering the period from April 2005 to April 2025. These indices were retrieved from the following website: [Federal Public Service Economy](#). These reference indices are computed by the “Agence Fédérale de la Dette”.

Then, fixed-rate mortgage monthly data from April 2005 to April 2025 were provided by the financial broker *Immotheke Finotheker* ([Immotheke Finotheker website](#)). In order to download the accurate data, we used the following parameters: “Type of Loan = 10 year fixed-rate”, “Duration = 20 years”, “Amount = €250,000”, and “Loan-to-value = 0-80”. After discussion with an employee of Immotheke Finotheker, initial rates for the variable mortgage simulations were taken through the same website. Actually, only the Type of Loan parameter was changed by “1 year fixed-rate”, “3 year fixed-rate”, and “5 year fixed-rate”.

Finally, to implement the swap method, Belgian OLO bond data were used. Since the loan repayment period is set to 10 years, we used OLO rates with maturities ranging from 1 to 10 years to calculate the corresponding swap rates. These monthly data were downloaded from Bloomberg for the period April 2005 - April 2025. The 10-year OLO rates were also used separately as part of a different method.

In fact, to ensure a robust and comprehensive analysis, three distinct fixed interest rate data series were used. Each one represents a different perspective on how fixed mortgage rates are determined. Immotheke reflects real rates offered to Belgian consumers by banks, including margins and market conditions. OLO 10-year yields are based on Belgian government bonds and serve as a reference for low-risk, long-term rates. Swap

rates come from the financial markets and are used by banks to set the cost of fixed-rate lending. It is worth noting that the correlation between Immotheker rates and the OLO and swap rate series reaches 96.25%, confirming the strong alignment between these different sources. Using these three datasets allows us to compare floating-rate mortgages with a wide range of realistic fixed-rate scenarios.

It is also important to note that none of these data considers the risk premium from the borrower, except the fixed rates provided by Immotheker Finotheker. Therefore, the risk premium was calculated and added to the other data. To compute the risk premium, we took the average monthly difference between the Immotheker rates and the 10-year OLO yields. We repeated the same process and calculated the average monthly difference between Immotheker's data and the swap rates. Finally, the average of these two figures was considered as the monthly risk premium, which amounts to 0.055% or 5.5 bps.

3.2 Simulation Framework

To evaluate the performance of each mortgage type, monthly simulations were performed based on historical data sets. Each simulation represents a new 10-year mortgage starting in a specific month between April 2005 and April 2015, for a total of 120 simulations. For each simulation, the repayment schedule was calculated under both variable rates tied to the corresponding indices and fixed interest rates, using three different approaches: a traditional fixed rate, a fixed rate derived from OLO bond yields, and a fixed rate based on swap rates.

All simulations assume a loan amount of €250,000 to be repaid over 120 months. The borrower profile and all loan terms remain identical. The only difference is whether the rate is fixed or variable. Monthly payments were calculated using standard amortization formulas, taking into account the interest rate applicable for each period.

All of this constitutes the historical analysis, which has several limitations. In fact, due to the limited period of available data, considering more than 10 years of maturity for the mortgage simulations was not possible. This is the reason why we then decided to use the Vasicek model to simulate longer interest rate trajectories, allowing for broader comparative analysis. Thanks to the Vasicek model, we simulated 100 interest rate paths over a 20-year horizon for each of the three reference indices (A, C, and E), which allowed us to compare the resulting 20-year mortgages with the fixed rate options.

After the historical analysis, the Vasicek model was employed to simulate interest rate

paths over a 20-year horizon, allowing for broader comparative analysis.

The entire model was implemented using RStudio, which allowed more flexible programming, integration of historical data, and visualization of the results.

Each approach will be detailed in the following pages.

3.3 Floating-Rate Mortgages

The three chosen types of floating-rate mortgages differ in how frequently the interest rate is revised over time:

- 1/1/1 loans allow a revision of the interest rate every year;
- 3/3/3 loans permit rate changes every three years;
- 5/5/5 loans involve a revision every five years.

In each of the three structures, the rate is adjusted based on the evolution of a particular reference index (A for 1/1/1, C for 3/3/3, or E for 5/5/5). These products offer different trade-offs between stability and reactivity to market conditions: the 1/1/1 offers frequent adaptability, while the 5/5/5 provides more predictable payments in the short term.

3.3.1 The 1/1/1 Mortgage

As a reminder, in a 1/1/1 mortgage structure, the interest rate is revised annually. According to Immotheke Finotheker, the initial annual interest rate (April 2005) is 3.08%. This rate remains constant during the first 12 months. From the 13th month onward, the interest rate is revised each year based on the evolution of the reference index A.

First, we had to convert the initial annual rate into a monthly rate with the following formula.

$$\text{Monthly Rate} = (1 + \text{Annual Rate})^{\frac{1}{12}} - 1 \quad (1)$$

After adding the risk premium of 5.5 bps, the initial monthly rate reaches 0.3081%

To ensure stability and prevent excessive fluctuations, caps and floors were implemented to limit how much the interest rate can increase or decrease over time. These constraints provide a balance between flexibility and borrower protection.

Local caps were added for specific time frames to more closely manage rate changes. The first local cap sets 1% as the maximum annual increase in interest rate that may be imposed after the first 12 months. The second extends the cap even longer after 24 months, with the maximum annual increase being 2%. These local restrictions prevent excessive rate jumps within short periods, ensuring a smoother evolution of interest rates.

In addition to these local constraints, a global cap was defined to limit the overall increase in interest rates. This cap was determined as the minimum of twice the initial annual rate or the initial rate plus 2%, ensuring that the rate does not exceed a long-term sustainable level. Since the model operates on a monthly basis, the global annual cap was converted into a equivalent monthly cap.

Similarly, to prevent the interest rate from dropping too low, the model implemented a global floor. In fact, banks generally suggest a floor equal to the opposite of the cap. This is actually defined as the greater of zero or the initial annual rate minus 2%. The floor ensures that interest rates are above a reasonable level and not unrealistic or even negative. Like the cap, the floor was also converted to a corresponding equivalent monthly floor.

By implementing these constraints, the model provides a well-balanced approach that allows interest rates to adapt to market conditions while ensuring the borrower's security against excessive volatility. This prevents extreme changes in monthly payments due to sudden rate fluctuations.

After that, a loop was created to simulate mortgages starting each month over 10 years.

For each simulation, a data frame was generated to store, for each month, the interest rate, the interest payment, the capital payment, the remaining amount, the monthly payment, and the discounted cash flows.

For each of the 120 loans, we first calculated the interest rate valid for the first year thanks to the monthly reference indices with the following formula.

$$\text{Current Rate} = \text{Initial Rate} + (\text{Current Index} - \text{Initial Index}) \quad (2)$$

In that formula, the initial rate is the 0.3081% from Immotheke.

Then, we calculated the monthly payment that considers the actualization factor D.

$$D = \frac{1}{1 + \text{Current Rate}} \quad (3)$$

$$\text{Monthly Payment} = \frac{\text{Remaining Amount}}{D} \times \frac{1 - D}{1 - D^{\text{remaining payments}}} \quad (4)$$

Inside the first loop, we created another one for each month of the loan. In this second loop, the interest rate will be updated each year starting from month 14. Indeed, the first payment will be done in month 2, as month 1 corresponds to the sale deed signature at the notary, which also corresponds to the fund disbursement. Then, the rate is constant for 12 months. For the first rate update, the first local cap must be respected, as well as the second local cap for the second update. Both global cap and floor must be respected during each update. In case the rate is updated, the new monthly payment will also be calculated.

For each month, after calculating the interest rate and the monthly payment, the interest and capital payments can be found.

$$\text{Interest Payment} = \text{Remaining Amount} \times \text{Interest Rate} \quad (5)$$

$$\text{Capital Payment} = \text{Monthly Payment} - \text{Interest Payment} \quad (6)$$

We can easily notice that the interest part will decrease over time as it is based on the remaining loan amount. It will be the opposite scenario for the principal payment.

After that, the remaining amount will be updated.

$$\text{Remaining Amount}_j = \text{Remaining Amount}_{j-1} - \text{Capital Payment}_j \quad (7)$$

In order to make comparisons with the other types of mortgages, the discounted cash flows were calculated for each month using the following formula.

$$\text{Discounted CF} = \frac{\text{Monthly Payment}}{(1 + \text{Current Rate})^{\text{Payment number}}} \quad (8)$$

Finally, all the simulations results were gathered in a data frame.

To illustrate the process, consider the beginning of the amortization table for the first simulated mortgage. All the steps to obtain the second line will be described in detail.

	Month	New_rate_r	Actualization_factor_D	Remaining_amount	Interest	Capital	Monthly_payment	Discounted_CF	Simulation
1	0	0.003081131	0.0000000	250000.00000	0.000000000	0.000	0.000	0.000	1
2	1	0.003081131	0.9969283	248274.95692	770.28280848	1725.043	2495.326	2487.868	1
3	2	0.003081131	0.9969283	246544.59876	764.96772436	1730.358	2495.326	2480.687	1
4	3	0.003081131	0.9969283	244808.90913	759.63626378	1735.690	2495.326	2473.714	1
5	4	0.003081131	0.9969283	243067.87162	754.28837626	1741.038	2495.326	2465.772	1

Figure 2: Beginning of the amortization table for the first simulated 1/1/1 mortgage.

This loan starts in April 2005, when the initial annual rate is 3.08%, as mentioned at the beginning of this sub-section. After converting it into a monthly rate and adding the risk premium, the interest rate amounts to

$$((1 + 0.0308)^{1/12} - 1) + 0.00055 = 0.003081$$

Then, we can compute the discount factor and find the first monthly payment, which will occur in May 2005. As no payment has been done yet, the remaining amount is the initial loan amount and the number of remaining payments is 120.

$$D = \frac{1}{1 + 0.003081} = 0.9969285$$

$$\text{Monthly Payment} = \frac{250000}{0.9969285} \times \frac{1 - 0.9969285}{1 - 0.9969285^{120}} = 2495.302$$

Now, we are able to find the interest and capital parts of the payment.

$$\text{Interest Payment} = 250000 \times 0.003081 = 770.25$$

$$\text{Capital Payment} = 2495.302 - 770.25 = 1725.052$$

The remaining loan balance is updated accordingly.

$$\text{Remaining Amount} = 250000 - 1725.052 = 248274.9$$

Finally, the discounted cash flows are computed.

$$\text{Discounted CF} = \frac{2495.302}{(1 + 0.003081)^1} = 2487.638$$

3.3.2 The 3/3/3 Mortgage

For the 3/3/3 mortgage type, the initial annual interest rate provided by Immotheker is 3.64% (April 2005). After converting it to a monthly rate and adding the fixed risk premium, we obtained an initial monthly rate of 0.3534%.

The simulation and amortization process follows the same structure as for the 1/1/1 mortgage. The only difference lies in the frequency of interest rate revisions: in a 3/3/3 mortgage, the rate is revised every three years instead of annually. Also, the rate is updated following the evolution of the reference index C.

Regarding interest rate caps and floors, only global limits were applied in the model. Although local caps may sometimes be used in practice, they are generally less common in this type of floating-rate mortgage.

3.3.3 The 5/5/5 Mortgage

For the 5/5/5 mortgage type, the initial annual interest rate indicated by Immotheker is 3.74% (April 2005). After conversion to a monthly rate and the addition of the fixed risk premium, this resulted in an initial monthly rate of 0.3614%.

The simulation and amortization process is conducted the same way as for the other variable-rate mortgage types. However, in the 5/5/5 structure, interest rate adjustments occur only every five years.

As with the 3/3/3 mortgage, only global caps and floors were applied. Local caps, while theoretically possible, are less common in the case of longer adjustment intervals such as in 5/5/5 mortgages and were therefore not included in the model.

3.4 Fixed-Rate Mortgages

Three different approaches were used to obtain fixed-rate data. Indeed, we wanted to ensure a robust comparison and capture potential differences in cost between various fixed-rate pricing sources. Firstly, we took the rates provided by Immotheker Finotheker. For the second technique, 10-year OLO yields were used. Lastly, we calculated corresponding swap rates based on OLO yields with maturities ranging from 1 to 10 years.

Normally, a fixed-rate scenario means that the interest rate remains unchanged throughout

the loan period. However, in the case of mortgages, refinancing options can be considered. Therefore, they were taken into account in all three methods.

3.4.1 Fixed-Rate from Immotheke

As for the other mortgage types, the first step was to download the interest rates and convert them into monthly data. In this scenario, the risk premium was already included in the original data set.

To evaluate the performance of fixed-rate mortgages with refinancing possibilities, we simulated 10-year loans across multiple starting dates. Each simulation begins at a different month, starting from April 2005.

For each loan, the initial interest rate is extracted based on the starting month. The monthly payment is then calculated using the standard annuity formula (see equation 4). Then, the following algorithm is used:

Loan Amortization Algorithm

```
For each month  $t$  from 2 to 121:  
    interest_payment $_t$  = current_rate * remaining_balance $_{t-1}$   
    capital_payment $_t$  = monthly_payment $_t$  - interest_payment $_t$   
    remaining_balance $_t$  = remaining_balance $_{t-1}$  - capital_payment $_t$ 
```

Each month, the refinancing option is evaluated by comparing the present value of the remaining payments under the initial contractual interest rate with that under the market rate applicable at that month.

To compute this present value (PV), the following algorithm was applied. It first computes the monthly payment using the standard annuity formula. Then, it simulates the amortization schedule over the remaining term. At the end, it provides the total present value of the monthly payments over the remaining term.

Present Value Calculation Algorithm

```

MonthlyPayment =  $\frac{\text{Principal} \times \text{Rate} \times (1 + \text{Rate})^n}{(1 + \text{Rate})^n - 1}$ 
PVtotal = 0
For t = 1 to n:
    DiscountFactort =  $(1 + \text{DiscountRate})^{-t}$ 
    PVt = MonthlyPayment × DiscountFactort
    PVtotal += PVt

```

If a refinancing opportunity is considered, a penalty equivalent to three months of interest must be paid, in addition to €350 of processing fee. These charges are not paid upfront but added to the remaining principal, increasing the loan balance.

The refinancing logic can be described as follows:

Refinancing Decision Algorithm

```

penalty = 3 * current_rate * remaining_balance
processing_fee = 350
total_penalty = penalty + processing_fee

PV_current = PV of future payments under contractual rate
PV_new = PV of future payments under market rate,
         calculated on (remaining_balance + total_penalty)

if PV_current - PV_new > 0:
    refinancing is beneficial for the borrower
    current_rate = new_rate
    remaining_balance += total_penalty
    recalculate monthly_payment using updated balance and new
    rate

```

This refinancing check is performed at each month of the loan, and only executed if the expected savings from refinancing exceed the refinancing cost.

Once this decision has been made, the discounted cash flow for that month is computed using formula 8.

In the end, all simulated mortgages are gathered in one data frame.

3.4.2 Fixed-Rate from 10-year OLO yields

This approach uses 10-year OLO yields as data for fixed-interest rate mortgages. This aligns with the methodology applied by Immotheker Finotheker. Indeed, the fixed rates they publish are directly derived from the 10-year OLO yields. Those data refer to the return an investor can expect from holding a Belgian government bond with a 10-year maturity.

To start the simulation and amortization process, we first converted the rates to monthly data and added the risk premium.

After that, the method followed is exactly the same as for the fixed-rate data provided by Immotheker.

3.4.3 Fixed-Rate from Swap Rate

The swap rate represents the fixed interest rate that a financial institution would accept in exchange for receiving floating-rate payments over a given maturity. In other words, it is the rate at which the present value of fixed payments equals the present value of expected floating payments over a certain period. This explains why this method was chosen.

First, swap rates needed to be calculated. Therefore, OLO yields (r) for maturity 1 until 10 years were downloaded. Then, these data were converted into discount factors.

$$DF_t = \frac{1}{(1 + r_t)^t} \quad (9)$$

An extra column with a value of 1 has also been added for "0Y" of maturity, since receiving €1 today has a present value of €1.

After, we calculated the sum of all future discount factors (excluding the "0Y" value). This sum represents the total present value of a stream of future payments of €1 over the term of the bond.

$$\sum_{t=1}^n DF_t = \sum_{t=1}^n \frac{1}{(1 + r_t)^t} \quad (10)$$

The next step was to compute annual forward rates, which are the implied interest rates between consecutive years. They were calculated using the difference between discount

factors of two successive maturities.

$$f_{t,t+1} = \frac{DF_t - DF_{t+1}}{DF_{t+1}} \quad (11)$$

Then, the code calculated weights for each year's forward rate. These weights were obtained by dividing each year's discount factor by the total sum of discounts factors computed before. They represent the present value proportion of each period. It is important to note that the weights always sum to 1.

$$w_t = \frac{DF_t}{\sum_{i=1}^n DF_i} \quad (12)$$

Finally, the swap rate was calculated as the weighted average of the forward rates.

$$\text{Swap Rate} = \sum_{t=1}^n w_t \times f_{t,t+1} \quad (13)$$

After, we converted the annual swap rates into monthly data and added the risk premium.

Then, the simulation and amortization process is exactly the same as for the two previous fixed-rate approaches.

3.5 The Vasicek Model

When considering models for analysing interest rate dynamics, the Vasicek model represents an appropriate choice. Its continuous-time formulation provides a flexible framework for examining interest rate movements at any point in time. This is necessary to capture interest rate behaviour on different time horizons, providing a detailed and dynamic understanding of interest rate movements.

The model equation is the following:

$$dr_t = \kappa(\theta - r_t) dt + \sigma dW_t \quad (14)$$

The parameterisation of the Vasicek model offers intuitive interpretations, making it particularly useful for analysis and understanding. For example, the speed of the mean reversion parameter (κ) represents how quickly interest rates return to their long-term

equilibrium (θ), while the volatility parameter (σ) quantifies the magnitude of interest rate fluctuations. These parameters provide a clear insight into the underlying dynamics driving interest rate movements. Another key strength of the Vasicek model is that it introduces randomness through Brownian motion (W_t), capturing the inherent unpredictability of financial markets. While the model acknowledges the stochastic nature of interest rate movements, it simplifies the process by assuming a constant volatility (σ), and thereby achieves a practical balance between realism and analytical simplicity.

In summary, the Vasicek model's ability to combine analytical precision with intuitive parameterisation makes it a powerful tool for understanding and modeling interest rate dynamics. Its continuous-time framework, and mean-reversion characteristic, along with the inclusion of constant stochastic volatility, make it an invaluable asset for financial analysts. Such simplicity and flexibility ensure that the Vasicek model remains the first choice for anyone who wants to analyse and predict interest rate movements with precision and clarity.

3.5.1 Calibration

Before simulating interest rate paths, we calibrated the model. Since the objective was to make simulations for floating rate mortgages, the data used to calibrate are the historical monthly rates of floating rate mortgages (Indices A, C, and E). These monthly rates were calculated on the basis of the formulas 2 and 1. Of course, we did not forget to add the risk premium.

Here are the formulas derived from the maximum likelihood estimator used for the Vasicek calibration:

$$x_t = r_t, \quad y_t = r_{t+1} \quad (15)$$

where:

- r_t : the observed monthly interest rate at month t
- r_{t+1} : the observed monthly interest rate at month $t + 1$

$$S_x = \sum_{t=1}^n x_t, \quad S_y = \sum_{t=1}^n y_t \quad (16)$$

$$S_{xx} = \sum_{t=1}^n x_t^2, \quad S_{xy} = \sum_{t=1}^n x_t y_t, \quad S_{yy} = \sum_{t=1}^n y_t^2 \quad (17)$$

$$\theta = \frac{S_y S_{xx} - S_x S_{xy}}{n(S_{xx} - S_{xy}) - (S_x^2 - S_x S_y)} \quad (18)$$

$$a = \frac{S_{xy} - \theta S_x - \theta S_y + n\theta^2}{S_{xx} - 2\theta S_x + n\theta^2} \quad (19)$$

$$\kappa = -\frac{\ln(a)}{dt} \quad (20)$$

$$\sigma^2 = \frac{1}{n} (S_{yy} - 2a S_{xy} + a^2 S_{xx} - 2\theta(1-a)(S_y - a S_x)) \quad (21)$$

3.5.2 Simulation

After, we proceeded to the simulation of 100 paths for each floating-rate type (Index A, C, and E), with a monthly time step and a time horizon of 20 years.

The following equation represents the analytical solution of the continuous-time Vasicek model. It allows simulation of interest rate paths using the exact distribution of the process, incorporating both the deterministic mean-reversion component and the stochastic shock.

$$r_{t+\Delta t} = r_t e^{-\kappa \Delta t} + \theta(1 - e^{-\kappa \Delta t}) + \sigma \sqrt{\frac{1 - e^{-2\kappa \Delta t}}{2\kappa}} \cdot \varepsilon_t \quad (22)$$

where:

- r_t is the short-term interest rate at time t ,
- κ is the speed of mean reversion,
- θ is the long-run equilibrium level of the interest rate,
- Δt is the time step,
- σ is the volatility of the process,

- $\varepsilon_t \sim \mathcal{N}(0, 1)$ is a standard normal random variable representing the shock from Brownian motion

It is important to note that a floor was added to prevent negative simulated rates, ensuring realistic economic behavior in the mortgage models.

3.5.3 Simulated Mortgages

Using the interest rate paths generated by the Vasicek model, we simulated 100 floating rate mortgage scenarios for each reference index, assuming a 20-year loan duration. For each simulated path, the amortization follows the same methodology described in Section 3.3. However, unlike the historical simulation where a new loan was initiated each month, here a single mortgage is simulated per path.

Since the main objective of this thesis is to compare fixed and floating interest rate mortgages, we also simulated 20-year fixed-rate mortgages using each of the three fixed-rate approaches previously described. Only one mortgage was simulated for each fixed rate type. The input data are the same as those used in Section 3.4, and the amortization process, including the refinancing mechanism, follows the procedure outlined in that section.

This method enables the comparison of mortgage scenarios over a longer repayment period and allows us to explore how different index trajectories could impact outcomes.

4 Results

In this section, we analyse and compare the results of the different mortgage types considered in this thesis. We begin by evaluating the performance of the three floating-rate mortgage structures (1/1/1, 3/3/3, and 5/5/5) based on historical index trajectories. The analysis focuses on the total amount paid over the 10-year repayment horizon, along with key distributional characteristics across all simulations.

We then turn to fixed-rate mortgage structures and examine the differences between the three fixed-rate pricing approaches described previously. This includes the impact of potential refinancing opportunities and how they affect overall payments.

Finally, we present a comparative overview of floating versus fixed rate mortgages, allowing a direct evaluation of the cost-effectiveness and risk profiles associated with each structure. The last part of the section explores simulated scenarios based on Vasicek-generated interest rate paths to assess how uncertainty could influence mortgage outcomes.

4.1 Floating-Rate Mortgages

As a reminder, simulations were performed for three different types of variable-rate mortgages. The first consists of an annual rate revision, the second of a revision every three years, and the last of a revision every five years.

4.1.1 Total Discounted Payments

The following box plot represents the total amount paid during the repayment period for each floating rate structure. In each box containing the 120 simulated mortgages, the red line represents the mean, while the black line indicates the median.

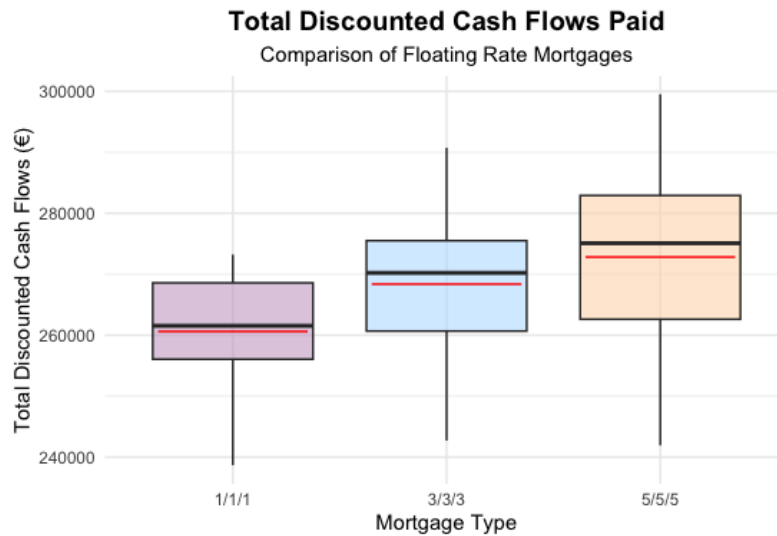


Figure 3: Total discounted payments for each floating-rate mortgage type (1/1/1, 3/3/3, and 5/5/5).

We can easily notice that the 1/1/1 mortgage has the lowest average total cost, which amounts to €260,000. This means that, on average, the borrower will pay less by opting for the annual revision. In fact, more frequent rate revisions allow the borrower to benefit sooner from falling interest rates, which reduces the total interest paid. In contrast, with longer fixed rate periods, borrowers may remain stuck with higher rates even when market rates fall.

In addition, the spread, which is represented by the height of the boxes and whiskers, increases from 1/1/1 to 5/5/5. This indicates that the variability in outcomes is higher for mortgages with less frequent rate revisions. Also, high-rate scenarios can lead to significantly higher costs with a 5/5/5 mortgage. Indeed, the top whisker for 5/5/5 reaches almost €300,000, while it is less than €275,000 for the 1/1/1 mortgage.

Moreover, the median shows the central value. In fact, 50% of the simulations resulted in a total payment below this value, and 50% above it. Unlike the mean, the median is not affected by outliers. Therefore, it provides a good indication of the "typical" amount paid for each mortgage type.

4.1.2 Global Cap and Floor

For each type of mortgage, we added a global cap and a global floor. These constraints must be respected at all rate revision moments. Thanks to the following table, we can give

comments regarding their activation.

	Cap_Binding_Frequency	Floor_Binding_Frequency	Type
1	0.030555556	0.3768519	1/1/1
2	0.016666667	0.5750000	3/3/3
3	0.008333333	0.5583333	5/5/5

Figure 4: Activation frequency for global cap and floor constraints for each mortgage type.

First, we can see that the cap constraint activation frequency is relatively low across all types, indicating that interest rates rarely reached the upper limit defined by the global cap.

In contrast, the frequency of activation of the floor constraint is significantly higher for all types of mortgage. For 3/3/3 and 5/5/5 mortgages, in more than half of the rate revision points, the interest rate hit the global floor. This suggests a prolonged low interest rate environment during the simulation period. This can be observed on the graph below. Actually, we noticed that the rate update months for which the floor constraint is active are mainly in the second half of the simulations. This is in accordance with the graph, which shows that interest rates were extremely low between 2016 and 2021. In fact, this corresponds to the period when the European Central Bank maintained its interest rates at very low levels in order to simulate the eurozone economy.

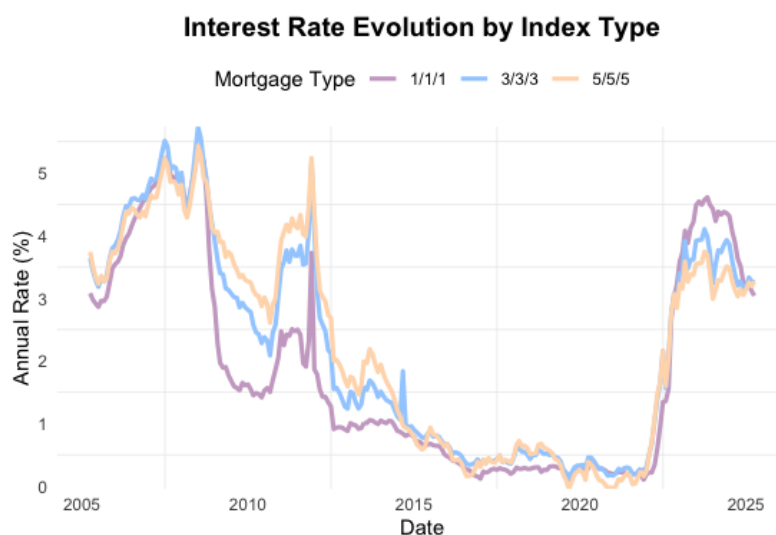


Figure 5: Evolution of annual interest rates.

4.1.3 Conclusion

In conclusion, the analysis of floating-rate mortgage structures highlights a clear trade-off between flexibility and risk. More frequent revision of the rate in mortgages, such as in the 1/1/1 structure, generally offers lower total payments by allowing borrowers to take advantage of falling interest rates more promptly. However, they may also expose borrowers to more frequent fluctuations in monthly payments. In contrast, the 5/5/5 mortgage, while offering greater payment stability, results in higher average interest costs and greater variability in outcomes. The frequent activation of floor constraints, further limited the potential benefits of rate reductions. In general, while short revision intervals appear more advantageous in terms of total cost, borrowers must weigh this benefit against the increased exposure to rate volatility.

4.2 Fixed-Rate Mortgages

Now, let us take a look at fixed-rate mortgages, which we have simulated thanks to three different input data sets.

4.2.1 Total Discounted Payments

According to Figure 6, which represents the total discounted cash flows paid depending on the mortgage input data, no significant differences are observed in terms of mean or median values. This indicates that, on average, all three data sets lead to similar mortgage costs over the 10-year period. This alignment helps to reinforce the robustness and reliability of the modeling framework as the use of different reference rates does not significantly change the expected payments over the loan duration.

However, we can see that the height of the green box is smaller than that of the other boxes. This means that Immotheker data offer less variability in outcome than the 10-year OLO yields and the swap rates. This can be explained by the fact that Immotheker rates reflect actual mortgage offers from banks, which are likely smoother and less sensitive to short-term market fluctuations than market-based indices such as OLO or swap rates. This can be observed on Figure 15.

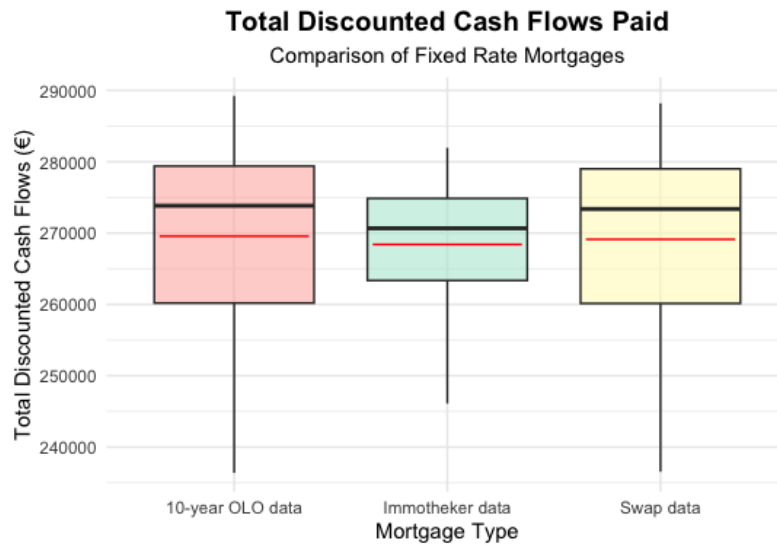


Figure 6: Total discounted payments for each fixed-rate mortgage type.

4.2.2 Refinancing Events

For all simulated fixed-rate mortgages, the refinancing option was considered each month. If the borrower opts for the new rate, he must pay a penalty equivalent to three months of interest plus €350 of processing fee. That cost is added on the remaining principal, increasing the loan balance. Therefore, for the new rate to be considered beneficial, the present value of the remaining payments under the current market rate must be lower than that under the contractual rate.

Over the 120 simulations performed for each fixed rate data set, a total of 641 refinancing events were recorded using Immotheke rates, compared to 889 for the OLO-based rates and 877 for the swap-based rates. Indeed, the evolution of Immotheke interest rates is relatively smooth throughout the period, while OLO and swap rates show more volatility, leading to more refinancing opportunities. Also, on average, refinancing results in savings of €3,709 when using Immotheke rates, compared to €5,741 with OLO-based rates and €5,688 with swap-based rates. This may be explained both by the fewer refinancing opportunities observed under Immotheke rates, and by the lower profitability of those opportunities, as the smoother evolution of the Immotheke rate curve tends to result in smaller interest rate differentials compared to the more volatile OLO and swap-based rates.

The histogram below shows the distribution of refinancing events according to the remaining term of the mortgage using Immotheke rates. We observe a clear upward trend:

refinancing becomes more frequent as the remaining term increases. In fact, the highest concentration of refinancing events occurs between 100 and 120 months. This suggests that many borrowers choose to refinance their fixed-rate mortgages when there are about 8 to 10 years remaining. Indeed, a longer remaining term allows borrowers to benefit from a larger reduction in total interest costs, making refinancing more attractive. Also, we can see that when the remaining term is less than 25 months, no refinancing events occur anymore. In fact, when the remaining duration of the loan becomes too short, the interest savings no longer justify the refinancing costs, making such operations less frequent.

As shown in Figures 16, and 17, the same patterns are observed for the mortgages simulated with 10-year OLO yields and swap rates.

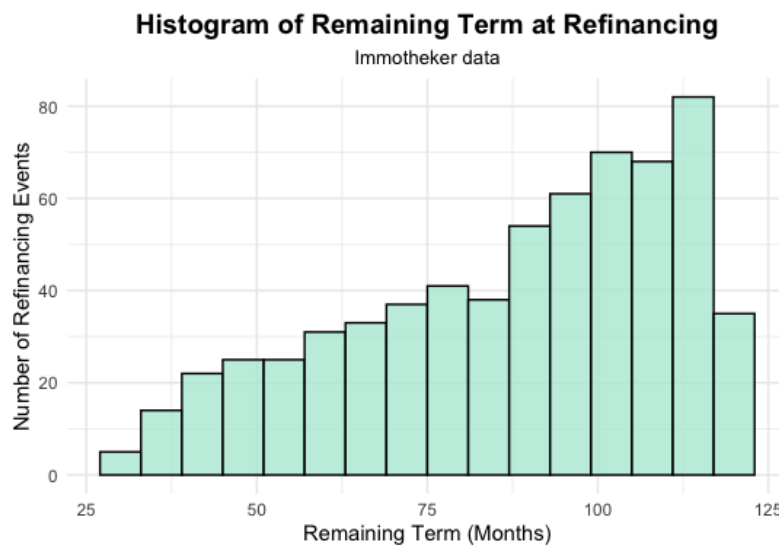


Figure 7: Distribution of refinancing events over time for fixed-rate mortgages based on Immotheke data.

The figure below represents the interest rate trajectory for the 25th simulated mortgage based on Immotheke data. Each red dotted line shows a refinancing event. Here, we can see that refinancing occurs 4 times.

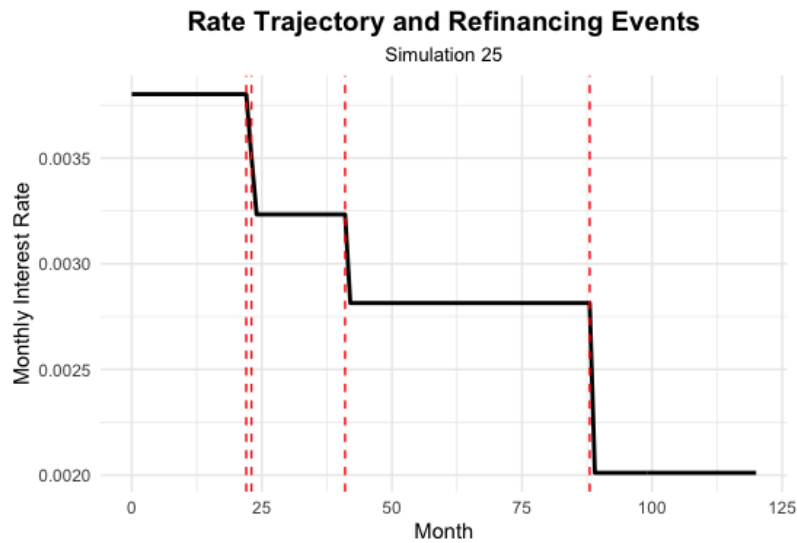


Figure 8: Rate evolution of the 25th simulated mortgage with data from Immotheke.

4.2.3 Conclusion

In conclusion, while the average cost of fixed-rate mortgages remains consistent across the three data sources, the frequency and benefits of refinancing may vary. More volatile market-based rates such as OLO and swap offer more frequent and more profitable opportunities to refinance than the smoother Immotheke rates. This highlights the importance of rate dynamics in shaping borrower outcomes, even within a fixed-rate framework.

4.3 Fixed vs. Floating Rate Mortgages

This section compares the performance of fixed and floating rate mortgage structures. The focus is on how they differ in terms of total cost and repayment dynamics.

4.3.1 Repayment Dynamic

The common pattern for all types of mortgage is the fact that the interest part of the monthly payment will decrease over time because it is based on the remaining loan amount. In contrast, the capital part will increase. This can be observed on the graph below that represents the monthly breakdown of capital and interest payments for the first simulation under four different interest rate types.

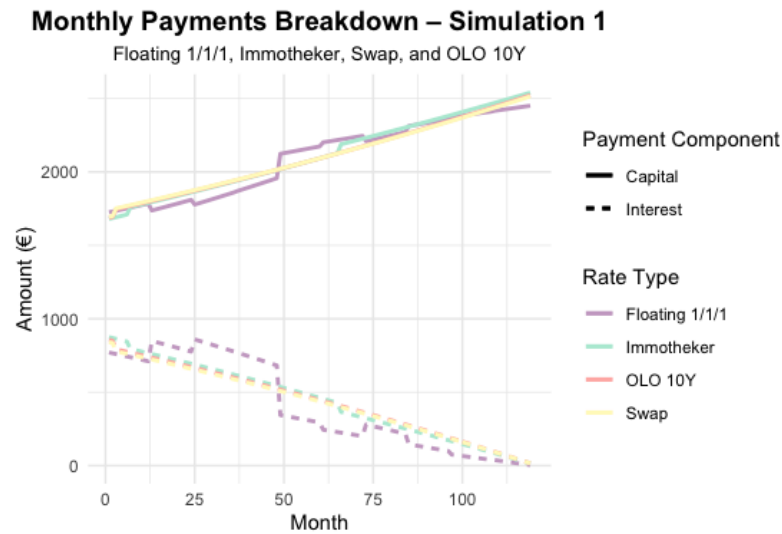


Figure 9: Evolution of capital and interest payments for the first simulation under Immotheker, 10-year OLO, swap and 1/1/1 floating rates.

For the three fixed-rate mortgages (Immotheker, OLO, and Swap), the repayment dynamic is relatively similar. Both the interest and capital components evolve gradually over time. When refinancing occurs, we can observe a sudden increase in capital for the following payments, as the penalty has been added.

On the other hand, the 1/1/1 floating mortgage has a less consistent trend. Each time the interest rate is revised, any upward rate adjustment leads to a sudden increase in interest payments, which consequently reduces the capital portion. Conversely, when the new rate is lower, interest drops and the capital portion increases more rapidly. These rate adjustments result in a more unpredictable payment trajectory compared to fixed-rate alternatives.

It is important to note that this example illustrates a 1/1/1 floating-rate loan, where the rate is revised every year. The less often the rate is revised, the smoother will be the trajectories of capital and interest. Figures 18, and 19 show the repayment patterns for floating-rate mortgages with fewer rate updates, namely 3/3/3 and 5/5/5.

4.3.2 Total Cost

Now, we will focus on the comparison of total costs between fixed and floating mortgages.

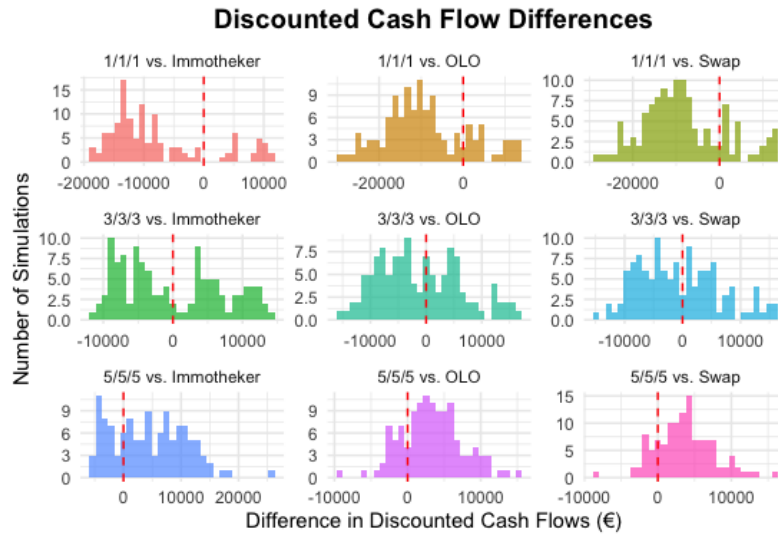


Figure 10: Histogram of discounted payment differences for each fixed vs. floating mortgage simulation scenario.

Figure 10 displays histograms of the differences in the total discounted cash flows paid between each floating-rate and fixed-rate mortgage type over the 120 simulations. Differences are calculated as (floating – fixed), meaning negative values indicate that floating-rate mortgages are cheaper.

The results show that the 1/1/1 mortgage type frequently leads to lower total costs, with distributions skewed toward the left. This is supported by Figure 20, which shows that the 1/1/1 mortgage is profitable in 81.67% of the cases against Immotheke, and 80% against both swap and OLO rates. In contrast, the 5/5/5 mortgage is profitable in fewer simulations (only 30% vs Immotheke, 22.5% vs OLO, and 17.5% vs Swap), with its distributions more centered to the right. The 3/3/3 mortgage shows a more balanced profile, with 55% profitability across all benchmarks, indicating a neutral cost performance. These results suggest that while shorter reset periods, such as the 1/1/1 mortgage type, involve more interest rate exposure, they also provide the highest potential for cost savings over the long term.

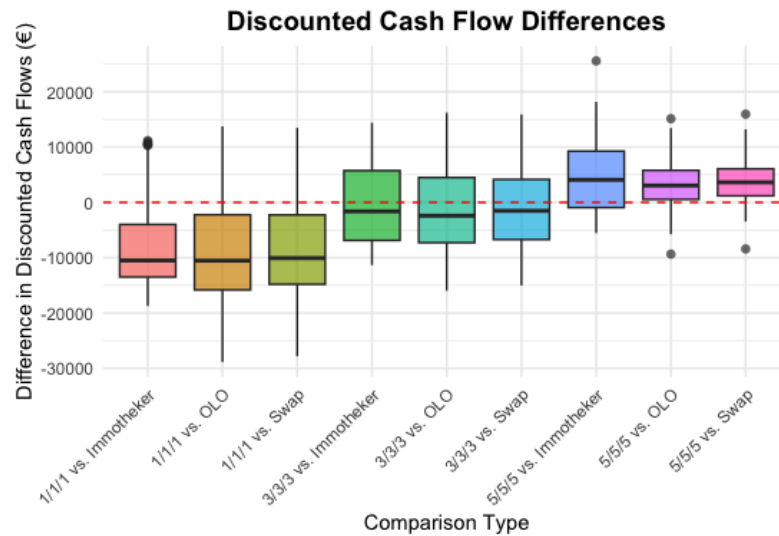


Figure 11: Boxplot of discounted payment differences for all combinations of fixed and floating mortgage types.

Figure 11 provides a detailed view of the distribution of total cost differences between all combinations of fixed vs. floating mortgages. The results confirm the findings from the histograms by showing that the 1/1/1 floating-rate mortgage has the lowest median discounted cost across all fixed-rate benchmarks, with distributions clearly skewed toward savings. This aligns with its high profitability percentages shown in Figure 20. The 3/3/3 option remains balanced with a median near zero, while the 5/5/5 mortgage tends to be more costly than the fixed options.

4.3.3 Conclusion

Overall, the comparison between fixed and floating-rate mortgages highlights a clear trade-off between cost stability and potential savings. While fixed-rate mortgages offer predictable repayment dynamics and smoother trajectories, floating-rate structures, especially the 1/1/1 type, can lead to significant cost reductions. Among the floating options, the 1/1/1 mortgage stands out as the most frequently cost-effective, though it also introduces more volatility in monthly payments. Conversely, the 5/5/5 mortgage behaves more like a fixed-rate loan in terms of stability but offers limited financial advantage. In the end, the choice between fixed and floating mortgage depends on the borrower's risk tolerance and expectations about future interest rate movements.

4.4 The Vasicek Model

This part evaluates variable-rate mortgage outcomes using interest rate scenarios generated by the Vasicek model. It covers the simulations, the key parameters sensitivity, and a comparison with fixed-rate mortgages.

4.4.1 Calibration and Simulation

As a reminder, the Vasicek model was calibrated using historical interest rate data from Index A, Index C, and then Index E.

For Index A, the estimated parameters are as follows : $\kappa = 0.1065$, $\theta = 0.0021$, $\sigma = 0.0006$.

For the two other indices, the parameters are slightly different, but still very similar to those of Index A.

Based on these parameters, 100 interest rate paths were simulated over a 20-year horizon with monthly steps. As shown in Figure 21, the historical path (in red) is always captured within the simulated trajectories. This confirms that the model produces realistic dynamics that is suitable for the simulation of mortgages under uncertainty.

The simulated paths for Indices C and E can also be found in the Appendices (Figures 22, and 23).

4.4.2 Sensitivity Analysis

To assess the robustness of the Vasicek model, a sensitivity analysis was performed on its three core parameters: the speed of mean reversion (κ), the long-term mean (θ), and the volatility (σ). Each parameter was varied while keeping the others constant to observe its influence on the evolution of the interest rate paths.

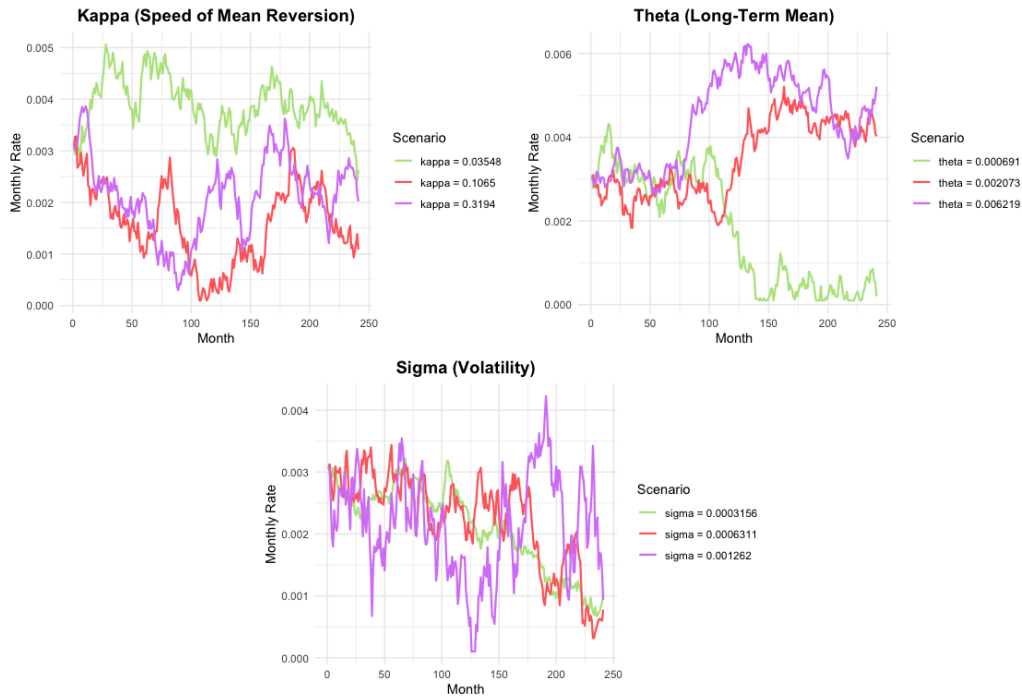


Figure 12: Sensitivity analysis of Vasicek parameters.

As shown in Figure 12, increasing κ leads to a faster reversion of the rate toward the mean, resulting in more stable paths. On the contrary, lower values of κ allow greater deviations over time. When changing θ , the overall level of the rate changes accordingly: a higher θ drives the rates upward, while a lower θ results in more downward trajectories. Finally, changes in σ primarily affect the dispersion of the paths. In fact, higher volatility creates more erratic movements, while lower σ values produce smoother trends.

This analysis confirms that each parameter plays a distinct role in shaping the rate dynamics and highlights the importance of accurate calibration for realistic simulations.

4.4.3 Comparison between Fixed and Floating-Rate Mortgages

To evaluate the cost-efficiency of floating-rate mortgages under stochastic interest rate scenarios, 100 mortgages were simulated for each index using Vasicek-modeled interest rate paths. These were then compared to the three fixed-rate benchmarks: Immothequer data, OLO 10-year yields, and swap rates. For each fixed-rate case, a single 20-year mortgage was simulated.

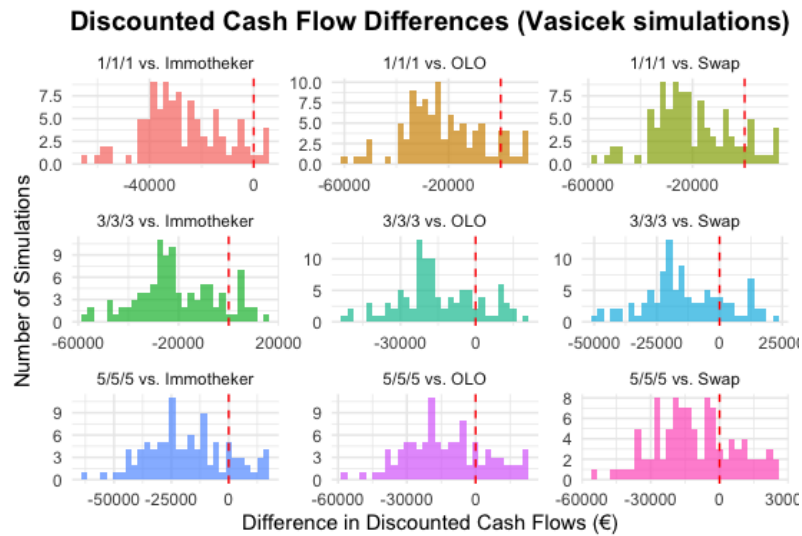


Figure 13: Histogram of discounted payment differences for each fixed vs. floating mortgage simulation scenario.

The Figure above presents histograms of the differences in discounted payments between each floating-rate and fixed-rate combination. Once again, negative values indicate that the floating-rate mortgage led to lower total payments than its fixed-rate counterpart.

The distributions for all comparisons are skewed to the left, suggesting strong cost advantages for the floating rate options. These findings are reinforced by Figure 24, which summarizes the profitability percentages of each floating-rate structure. In fact, the 1/1/1 floating mortgage is the most advantageous, outperforming Immotheke in 95% of the simulations, and OLO and swap in 89% and 86% respectively. The 3/3/3 and 5/5/5 mortgages also show strong performance, with profitability percentages consistently above 70%. Compared to the results under historical data, floating-rate mortgages appear even more favorable under stochastic interest rate paths, with higher profitability and more pronounced cost savings. This result is also influenced by the 20-year maturity used in the Vasicek simulations, instead of the 10-year horizon applied in the historical data analysis.

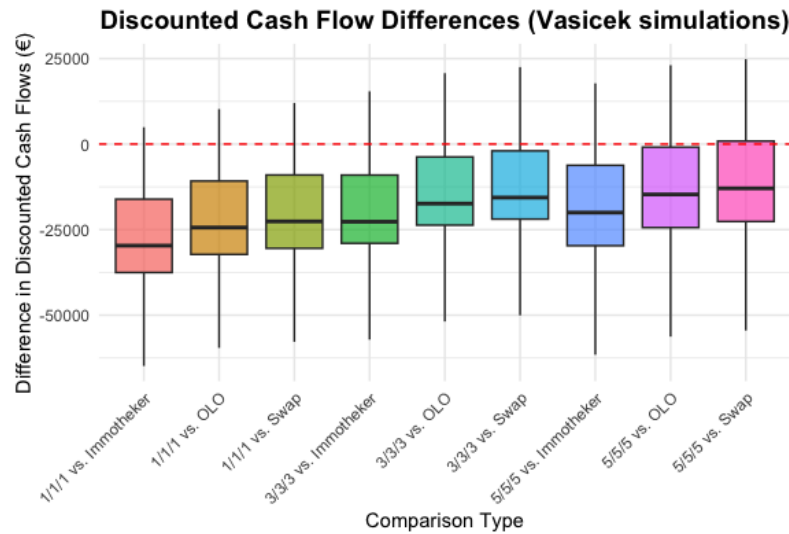


Figure 14: Boxplot of discounted payment differences for all combinations of fixed and floating mortgage types.

Figure 14 complements the histogram analysis by providing boxplots for all fixed vs. floating comparisons. These boxplots highlight the distribution of outcomes across simulations. Across all comparisons, the results are relatively consistent: floating-rate structures outperform their fixed-rate counterparts in a great majority of the cases. Indeed, each type of floating rate exhibits negative median values, regardless of the fixed-rate benchmark. We can notice that, with lower medians, the 1/1/1 mortgage remains slightly the most advantageous.

4.4.4 Conclusion

In conclusion, the Vasicek model provides a powerful framework for simulating realistic interest rate scenarios and assessing the performance of floating-rate mortgages under uncertainty. The calibration based on historical data led to plausible rate dynamics, while the sensitivity analysis confirmed the model's robustness to parameter changes. The Vasicek simulations on a 20-year maturity show that floating-rate mortgages consistently outperform fixed-rate options in terms of total discounted cost. This advantage is the strongest for the 1/1/1 structure, but remains significant even for the 3/3/3 and 5/5/5 options.

5 Discussion, Limits and Conclusion

5.1 Discussion

The findings of this thesis highlight the clear contrast between fixed and floating-rate mortgage structures. The most consistently result is the cost-effectiveness advantage of the 1/1/1 floating-rate mortgage. Indeed, in both the historical and Vasicek-based simulations, this structure led to the lowest total discounted payments in the vast majority of cases. Annually adjusting interest rates allows the borrowers to enjoy the benefits of falling rates sooner, thereby reducing total payments.

But such a flexibility comes at a cost. Higher frequency of rate revisions implies higher payment variability, which could expose the borrowers to uncertainty and complicate budget planning. While the 3/3/3 and 5/5/5 structures offer more stability, they reduce the ability to react to favorable rate movements. As a result, they generally resulted in higher average costs and lower profitability compared to the 1/1/1 structure.

Conversely, fixed-rate mortgages deliver repayment certainty and protection against rising rates, but they also revealed limitations. Although the average total cost for Immotheke, OLO, and swap-based fixed-rate mortgages was relatively close, refinance activity differed. The number and profitability of refinancing events were higher with OLO and swap-based mortgages, because they are more volatile in rates. In contrast, Immotheke rates follow smoother trajectories, which limited both the number and magnitude of refinancing opportunities.

The Vasicek simulations further emphasized these observations. Simulated over a 20-year horizon, floating-rate mortgages dominate fixed-rate alternatives in terms of discounted cost. The distribution of outcomes was highly skewed in favor of floating forms, with very high levels of profitability in all comparisons. In fact, the advantage of floating rates became even more pronounced under the Vasicek framework.

It is important to note that these results depend on the initial assumptions used in the simulations, such as the loan amount, the duration, and the interest rate scenarios. Different parameters or economic conditions could lead to significantly different outcomes. Therefore, the findings should be interpreted within the context of the specific settings chosen for this analysis.

5.2 Limits

Despite the robustness of the simulation framework developed in this thesis to compare various mortgage strategies, several limitations should be acknowledged.

First, the model relies on historical interest rates and simulated interest rate paths based on the Vasicek model. Although these provide a realistic foundation, they are a representation of what has occurred in the past or theoretical projections and do not account for future economic shocks, actions from the central bank, or credit and inflation movements. In fact, the results are conditional on the accuracy and relevance of these rate dynamics.

Second, the borrower profile used in the simulations is fixed and simplified. Indeed, all simulations assume a constant loan amount, maturity, and monthly repayment capacity. In reality, borrower characteristics, such as income levels, risk tolerance, or life events, can significantly influence mortgage choices and refinancing decisions. By not incorporating these behavioural elements, the analysis may lack a certain real-world realism.

In addition, the model is based on perfect repayment. In fact, there is no credit risk or default by borrowers considered. This assumption simplifies the simulation but does not reflect the reality that some borrowers may experience financial distress, which would affect both the repayment performance and the refinancing eligibility.

In summary, while this thesis offers a rigorous and structured framework for simulating and comparing mortgage repayment strategies, its findings should be interpreted with caution. The model can be extended in the future by incorporating, for example, more sophisticated borrower profiles or credit risk, in order to allow even more realistic evaluation of mortgage options.

5.3 Conclusion

This thesis examines the comparative performance of fixed and floating-rate mortgages using both historical data and simulated interest rate paths. The results show that floating-rate mortgages, particularly those with frequent revisions, tend to offer lower overall costs, while fixed-rate options provide greater stability and protection against rate volatility.

Ultimately, the optimal choice will depend on borrower profiles and market expectations. Mortgage strategies must remain flexible, as results are very sensitive to interest rate movements, loan term, and refinancing options. In a changing financial environment, informed and adaptive decision-making remains the key.

6 Appendices

6.1 Fixed-Rate Mortgages

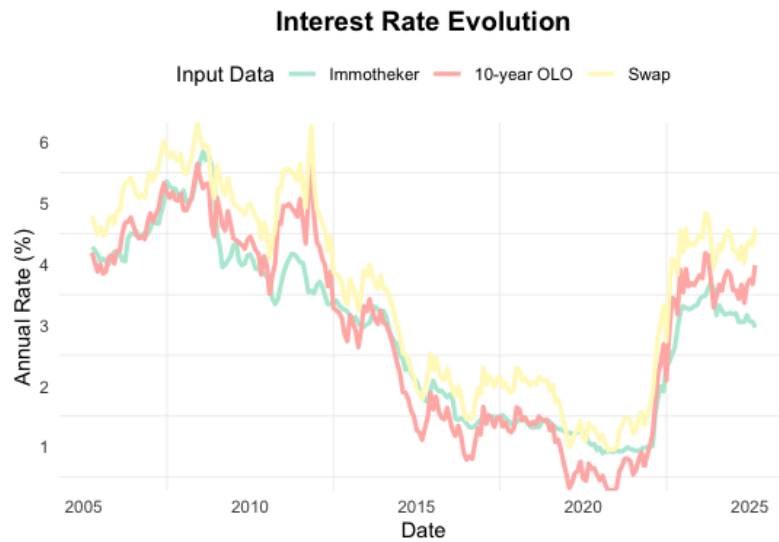


Figure 15: Evolution of the rates based on different input data.

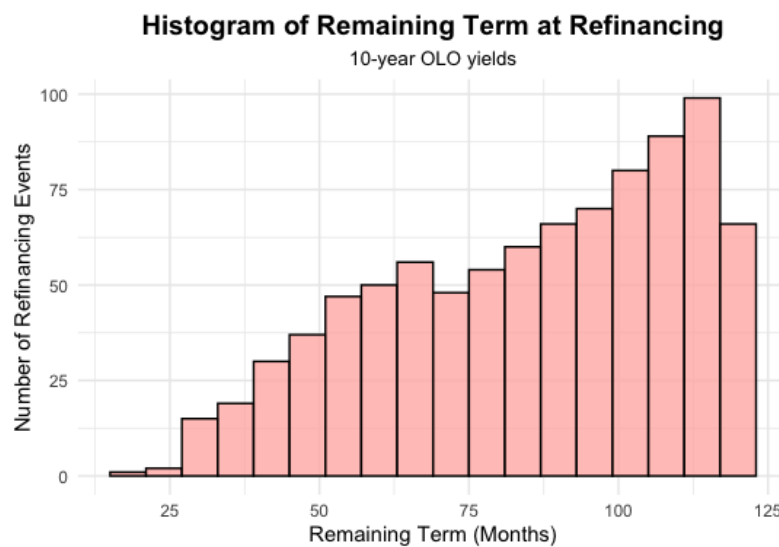


Figure 16: Distribution of refinancing events over time for fixed-rate mortgages based on 10-year OLO data.

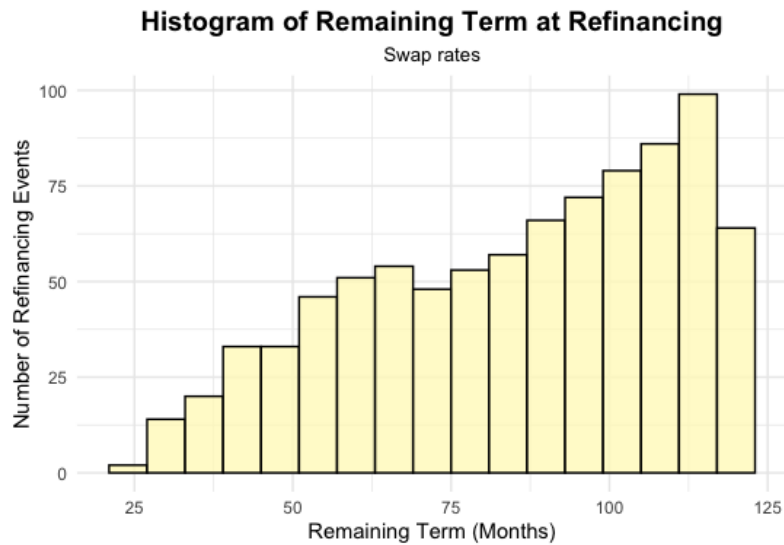


Figure 17: Distribution of refinancing events over time for fixed-rate mortgages based on swap rates.

6.2 Fixed vs. Floating Rate Mortgages

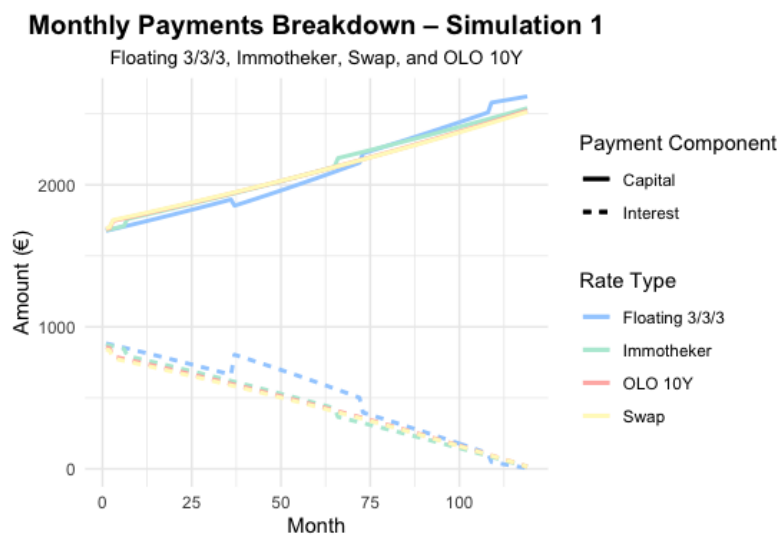


Figure 18: Evolution of capital and interest payments for the first simulation under Immotheker, 10-year OLO, swap and 3/3/3 floating rates.

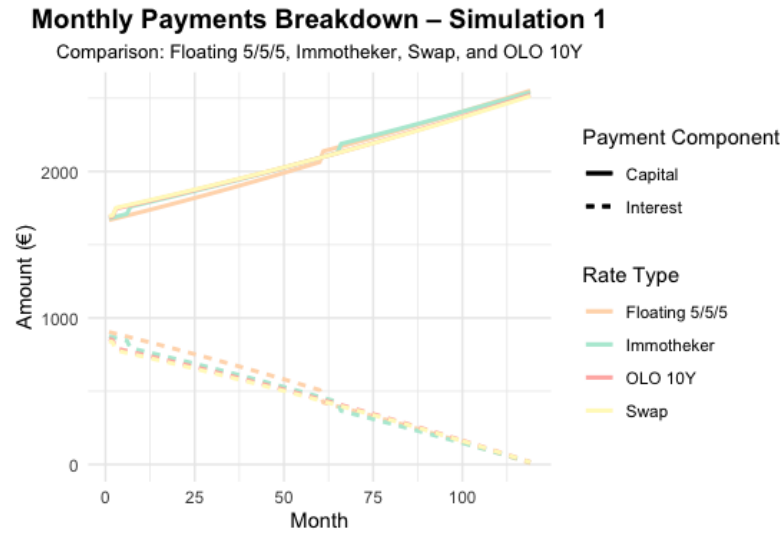


Figure 19: Evolution of capital and interest payments for the first simulation under Immotheke, 10-year OLO, swap and 5/5/5 floating rates.

	Comparison	Percent_Profitable
1	1/1/1 vs Immotheke	81.67
2	3/3/3 vs Immotheke	55.00
3	5/5/5 vs Immotheke	30.00
4	1/1/1 vs Swap	80.00
5	3/3/3 vs Swap	55.00
6	5/5/5 vs Swap	17.50
7	1/1/1 vs OLO	80.00
8	3/3/3 vs OLO	55.00
9	5/5/5 vs OLO	22.50

Figure 20: Table representing the profitability percentages of floating-rate compared to fixed-rate mortgages.

6.3 The Vasicek Model

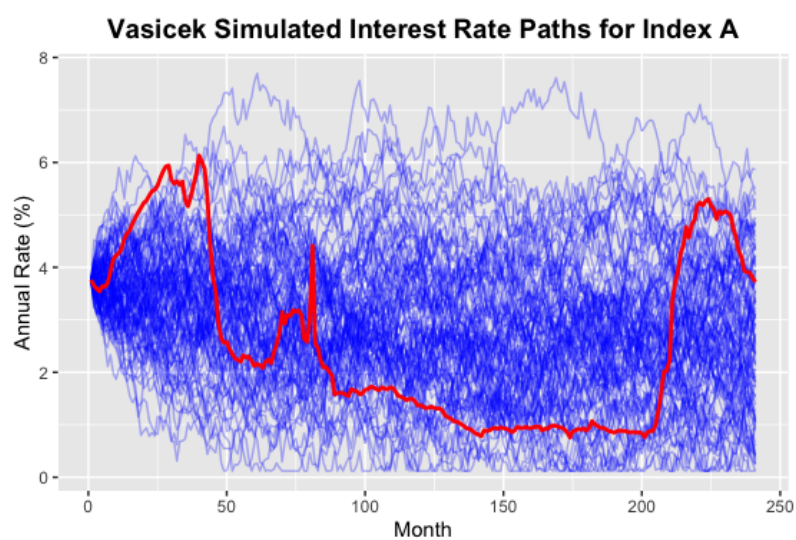


Figure 21: Vasicek simulations for Index A.

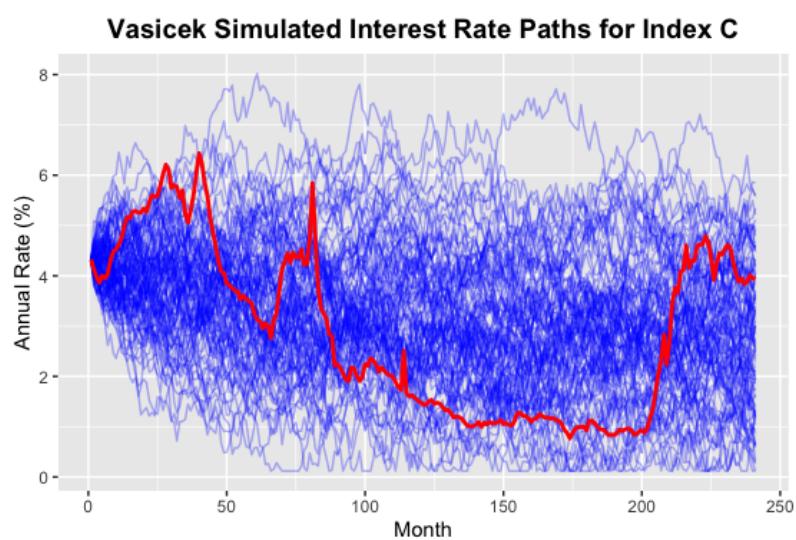


Figure 22: Vasicek simulations for Index C.

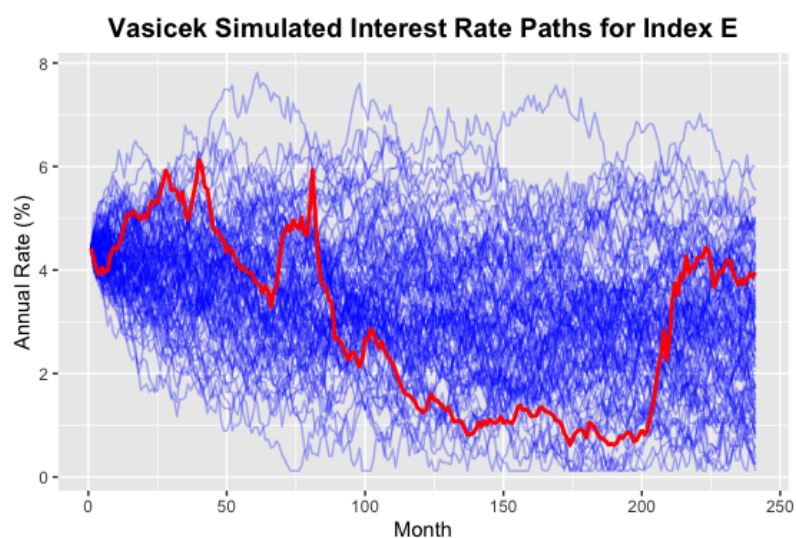


Figure 23: Vasicek simulations for Index E.

	Comparison	Percent_Profitable
1	1/1/1 vs Immotheker	95
2	3/3/3 vs Immotheker	87
3	5/5/5 vs Immotheker	82
4	1/1/1 vs Swap	86
5	3/3/3 vs Swap	79
6	5/5/5 vs Swap	73
7	1/1/1 vs OLO	89
8	3/3/3 vs OLO	81
9	5/5/5 vs OLO	76

Figure 24: Table representing the profitability percentages of floating-rate compared to fixed-rate mortgages.

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