Chapter 9
Prepayment Risk in Banking: Empirical Evidence from the Czech Republic

Petr Hanzlík and Petr Teplý

Abstract This paper deals with prepayment risks in banking and provides empirical evidence from the Czech banking sector. The prepayment risk of a loan can be viewed as an embedded option for a client to refinance his mortgage with a lower interest rate. Conversely, it holds that the clients' profit means a loss to the bank as a mortgage provider. Our analysis quantifies the impact of early repayment of a mortgage on the balance sheets of three different types of banks, which differ in the structure of their financing. In particular, we examine the negative effects of prepaid mortgages on the interest margins of these banks. The results of models have shown that these prepayments risks not only were theoretical, but they were also reflected in the decreasing net interest margin of the Czech banking sector in the 2019–2020 period.

Key words Asset liability management · Bank · Interest rate · Mortgage · Prepayment risk

9.1 Introduction

Prepayment risk is an important type of risk to be considered by every bank. Choudhry (2018, p. 107) defines it as "the risk associated with the early unscheduled return of principal on an instrument. … This risk also extends to typical retail lending products (for instance unsecured loans, mortgages, and vehicle finance)." Therefore, it has to be considered especially by those banks whose assets consist, to a large extent, of long-term retail loans, particularly mortgages. The prepayment risk

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may result in a decrease in banks' profitability in times of decreasing market interest rates. In such circumstances, bank clients have incentives to refinance their existing loans with higher interest rates by means of new loans with lower interest rates. In times of increasing rates, the prepayment risk may tend to decrease as, in such cases, clients would prefer to stick to previously contracted lower rates. However, the banks may experience higher default rates when the mortgages are repriced at the end of the fixation period to higher rates. Such increase in mortgage defaults caused by a combination of increasing interest rates and house price bubble occurred in the United States in 2007 and 2008 and contributed to the start of the global financial crisis (Mayer et al., 2009). The prepayment risk may be, to some extent, limited by contractual terms or legal provisions that specify the circumstances in which the loan can be prepaid. On the other hand, the legislation may be also designed in favor of the clients and thus contribute to the prepayment risk.

Our paper provides a case study of the mortgage market in the Czech Republic. The legislation in the Czech Republic effective since December 1, 2016 (Act No. 257/2016 Coll. on Consumer Loan, which transposed European Directive 2014/17/EU to Czech law) allowed for an interpretation by the Czech National Bank that the bank can charge the client only a very limited scope of the costs related to the prepayment of a loan. This interpretation leads to a higher probability of the materialization of prepayment risks in the Czech banking sector by lowering the costs of the prepayment option for the client.

Our analysis thus focuses on the impact of prepayment risk, defined as the risk of a fully repaid mortgage balance (but foregone interest) prior to the scheduled or contracted maturity, on the Czech banking sector. The remainder of the paper is organized as follows: in Sect. 9.2, we discuss key basic terms (embedded options of a bond and of a bank loan) needed for our research. Section 9.3 presents the methodology applied (case study on the interest rate risk of a bank and the net present value concept of a bank's total loss). In Sect. 9.4, we undertake an empirical analysis and compute the impact of early repayment of a mortgage on the balance sheets of three different types of banks. The last section concludes the paper.

9.2 Theoretical Part

9.2.1 Embedded Options of a Bond

In this section, we provide theoretical context, which will serve as the basis for our empirical research. In the financial markets, the problem of early repayment of a mortgage is similar to the problem of valuing callable bonds. Fabozzi (2015) defines *a callable bond as a bond in which the bondholder has sold the issuer a call option that allows the issuer to repurchase the contractual cash flows of the bond from the time the bond is first callable until the maturity date.* The call feature is a special feature of a bond or other financial instruments that give creditors and/or debtors the right to take action in the future against their counterparty. The embedded option is

an integral part of a financial instrument and is generally not separately tradable. One financial instrument may include more embedded options. The value of a callable bond is then expressed as the difference between the value of a non-callable bond and the value of the call option.

The call option protects the borrower or lender from unexpected changes in market interest rates (i.e., against price loss, which may arise from a decrease/increase of the interest rate between the issue date and the maturity date). Fabozzi (2004) lists a call option as the most typical embedded option, which gives the right to the debtor to repay his debt before an agreed maturity at a preagreed upon price (serving as a de facto ceiling on the price of the bond). This fact favors the borrower in the event of a fall in market interest rates because it gives him the opportunity to refinance debt under more favorable conditions. On a related note, Fabozzi (2004) introduces a put option on the market as a typical option to protect the lender when interest rates go up. In the remainder of our paper, we will focus primarily on the impact of the call option, which favors the borrower during decreasing market interest rates and also results in the lender's (bank) loss. Recently, two embedded options have been examined in the Czech financial market: construction savings by Horváth and Teplý (2013) and savings accounts by Džmuráňová and Teplý (2016).

9.2.2 Embedded Options of a Bank Loan

The prepayment risk of a loan represents an embedded option for a client to refinance his bank loan (e.g., a mortgage) for a lower interest rate. When the client exercises his early repayment option, he can repay the remaining balance of the loan (and forego future interest payments) before its maturity, which is better for him because this represents a lower implied interest rate. Obviously, this client's profit means a loss (of foregone interest payments less the risk of a default of an outstanding loan) to the bank as a mortgage provider. Moreover, the early mortgage repayment will have an impact on the interest rate position of the bank, as will be discussed later.

Hayre and Young (2004) highlight five main causes of premature repayment of a mortgage: replacement of housing (prepayment rate depends on the replacement of existing homes), refinancing (full early repayment for a new loan for better conditions), default (full repayment of the house as a seized collateral), partial prepayment (the client prepays part of the loan and shortens the original maturity), and full payment (e.g., in the case of destruction of the house by a natural disaster). However, it is necessary to distinguish the different sensitivities of the client's willingness to prepay a mortgage. While interest rates are decreasing, sensitivity is high. In contrast, sensitivity can be quite minimal in the case of solving life situations, such as divorce or the settlement of inheritance.

9.2.3 Prepayment Risk

Prepayment or Early Redemption Risk: applies on fixed-rate loans and deposits, where customers have the right (or an option) to repay loans or redeem deposits ahead of the scheduled maturity date, on payment of an early repayment or redemption charge (Choudhry, 2018, p. 1015). Banks in different countries handle the prepayment risk on mortgages differently. In countries such as the United States or the United Kingdom, the risk is transferred, via a process known as securitization, to the investors buying mortgage-backed securities (MBS) issued by a special purpose entity, to which the mortgages are sold by the originating bank. On the other hand, in many European countries, including Germany or the Czech Republic, the prepayment risk remains on the banks' balance sheets and the mortgages are funded either by the issuance of covered bonds or by retail deposits.

The existing literature on prepayment risk focuses mainly on the prepayment risk securitized through MBS in the United States (Becketti, 1988) or option-adjusted valuation of MBS related to the prepayment risk (Levin & Davidson, 2005). Kau et al. (1992) provide a generalized valuation model for fixed-rate mortgages (FRM). A paper by Ambrose and LaCour-Little (2001) deals with prepayment risk in adjustable-rate mortgages (ARM) and its securitization through MBS and provides evidence that prepayment risk is much less important for ARM than for FRM. Chernov et al. (2018) developed a reduced-form modeling framework to observe the implied prepayment function in which the prepayment rates are influenced by, besides interest rates, other macroeconomic factors.

9.3 Methodology

Our paper uses two methodological approaches. First, we present a case study on the interest rate risk of a bank through the bank's ALM. Second, we apply a net present value concept for the calculation of the bank's losses that resulted from lower interest income.

9.3.1 Case Study on the Interest Rate Risk of a Bank

The impact of early repayment of a mortgage can be illustrated by a bank's asset-liability-department (ALM) problem. For example, for a mortgage with a 5-year fixed term, the bank would need to offset its risk by finding adequate resources, such as an interest rate swap with the same maturity (a 5-year bank liability). If a mortgage is terminated before its contractual maturity, the bank's ALM should ensure that such a situation is balanced in the bank's balance sheet by means of a substitute transaction (e.g., by replacing the original source of mortgage funding with a new

instrument with a shorter maturity). This problem becomes significant in a low-interest-rate environment. For simplicity, let us assume that a bank has two parts of its portfolio: the first part is funded at recent low interest rates, and the second one is funded at past high interest rates. Figures 9.1 and 9.2 below illustrate this interest rate risk based on the development of real yield curves in the Czech Republic valid between December 31, 2000, and December 31, 2005, and between September

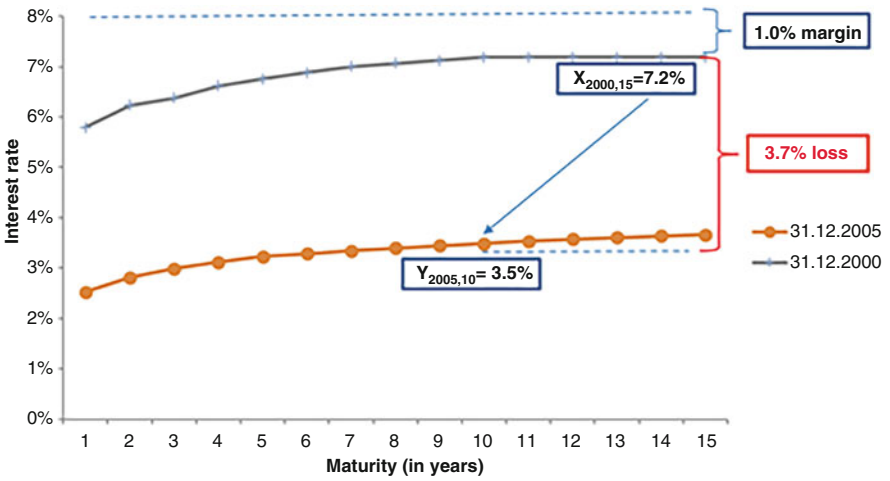

Fig. 9.1 Interest rate risk of the Bank as of 31 December 2005. (Source: Authors. Note: Loss from funding $= X_{(2000,15)} - Y_{(2005,10)} = 7.2\% - 3.5\% = 3.7\%$, where $X_{(2000,15)} =$ 15-year interest rate in 2000 and $Y_{(2005,10)} =$ 10-year interest rate in 2005)

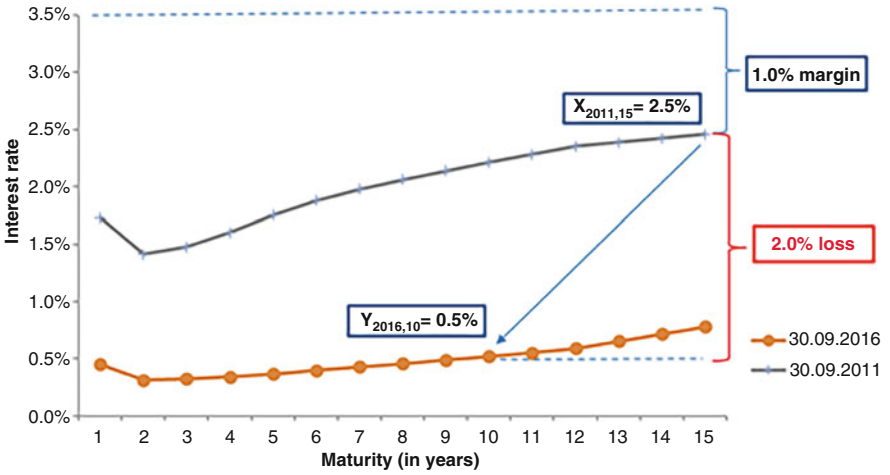

Fig. 9.2 Interest rate risk of the Bank as of September 30, 2011. (Source: Authors. Note: Loss on funding $= X_{(2011,15)} - Y_{(2016,10)} = 2.5\% - 0.5\% = 2.0\%$, where $X_{(2011,15)} =$ 15-year interest rate in 2011 and $Y_{(2016,10)} =$ 10-year interest rate in 2016)

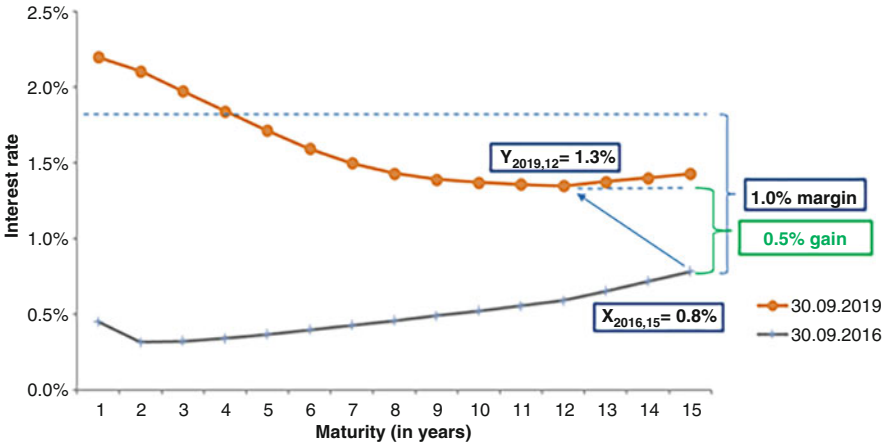

Fig. 9.3 Interest rate risk of the Bank as of September 30, 2016. (Source: Authors. Note: Gain from funding = $Y_{(2019,12)} - X_{(2016,15)} = 1.3\% - 0.8\% = 0.5\%$, where $X_{(2016,15)}$ = 15-year interest rate in 2016 and $Y_{(2019,12)}$ = 12-year interest rate in 2019)

30, 2011, and September 30, 2016. Let us suppose a bank (denoted as "the Bank") entered a 15-year fixed-rate payer swap on December 31, 2000, with a fixed rate of 7.2%[1] to finance a mortgage on that day with a 1% margin[2] (i.e., a total rate of 8.2%). However, 5 years later, in 2005, the mortgage was prepaid, and the Bank put the money raised from the mortgage prepayment on the market through a 3.5% fix rate receiver swap for the remaining 10 years, implying a loss of 3.7%[3] for the period 2006–2015, as displayed in Fig. 9.1. A similar situation is illustrated in Fig. 9.2, where the bank entered a 15-year fixed-rate payer swap on September 30, 2011, with a fixed rate of 2.5% to finance a mortgage on that day with a 1% margin (i.e., a total rate of 3.5%). However, 5 years later, in 2016, the mortgage was prepaid in a market environment in which the Bank was able to place the money raised from the prepayment on the market through a 0.5% fixed-rate receiver swap for the remaining 10 years.

In contrast to the situation of decreasing market rates depicted in Figs. 9.1 and 9.2, we identified an opposite situation of a period of increasing market rates in Fig. 9.3 between September 30, 2016, and September 30, 2019. In this case, the

[1] It means that the Bank was receiving a variable rate based on a 1-month Prague Interbank Offered Rate (PRIBOR), for instance. In practice, banks are hedging their fixed-rate assets, such as mortgages, by entering into fixed-rate payer swaps, while the actual funding of the balance sheet comes either from deposits or issued (covered) bonds.

[2] The nominal value of the mortgage is not important for our illustrative calculation. Also, for simplification, we neglect the amount of the fee paid by the client for this prepayment on December 31, 2015 (i.e., the Bank's compensation costs payable by the client—the option adjusted spread (OAS) rate—is equal to 0).

[3] 3.7% = 7.2% − 3.5% (loss on funding = funding costs − a new swap interest rate). In fact, the total loss for the bank is 4.7% = 3.7% + 1 % (loss on funding + margin).

prepayment is rather desirable for the Bank since it can put the money from prepayment into the fixed-rate receiver swap for a higher rate (1.3%) than at the time of the loan origination (0.8%). However, in such an event, the Bank still loses the 1% margin in case the money is placed on the market instead of being used for the provision of a new mortgage with the same margin.

9.3.2 The Net Present Value of a Bank's Total Loss

If we want to calculate the total loss for the whole 2006–2015 period, it is possible to use a standard formula for discounted cash flows:

$$PV = \sum_{t=1}^{T} \frac{CF_t}{(1 + r_t)^t}$$

where

PV = present value of a loss
CF_t = cash flow in a given year
r_t = interest rate in a given year
t = given year
T = end of the period

Let us assume that the Bank will provide a mortgage of CZK 1,000,000, then an annual loss of CZK 37,000 (3.7% loss from funding) was generated over the entire period, with the interest rate corresponding to the yield curve as of December 31, 2005 (see also Fig. 9.1):

$$\begin{aligned} \text{Loss} &= \frac{CF_1}{(1 + r_1)^1} + \frac{CF_1}{(1 + r_1)^1} + \frac{CF_2}{(1 + r_2)^2} + \ldots + \frac{CF_{10}}{(1 + r_{10})^{10}} \\ &= \frac{37\,000}{(1 + 2.5\%)^1} + \frac{37\,000}{(1 + 2.8\%)^2} + \ldots + \frac{37\,000}{(1 + 3.5\%)^{10}} = 310,900 \end{aligned}$$

The loss can be understood as a bank's cost in a situation when a counterparty (such as a corporate client or other banks) would terminate a swap contract. As a result, the Bank would have to conclude a new contract as of December 31, 2005, but at a lower rate (3.5% instead of the original 7.2% as of December 31, 2000). The total loss for the bank discounted as of December 31, 2015, arising from the swap contract termination amounted to CZK 310,900 over the 10-year period, which corresponds to a high volume since it is 31.09% of the nominal value of the loan.

9.4 Empirical Part

In this section, we provide the quantification of the impact of early repayment of a mortgage on three types of banks with different costs of funding. First, we provide a model of banks' portfolios without mortgage prepayment and then a model with mortgage prepayment. We distinguish three different periods of decreasing interest rates (2006–2011), low interest rates (2012–2017), and increasing interest rates (2017–2020).

9.4.1 Modeling Periods

9.4.1.1 Decreasing Interest Rates (2006–2011)

The period 2006–2011 is, in our paper, considered a time of decreasing interest rate, although during the years 2006–2008, the rates were in fact increasing, as shown in Fig. 9.4. However, in 2008, they started to drop quickly due to the global financial crisis. For a detailed analysis of the performance of the Czech banking sector in this period, we refer to Černohorská et al. (2017) or Palečková (2017).

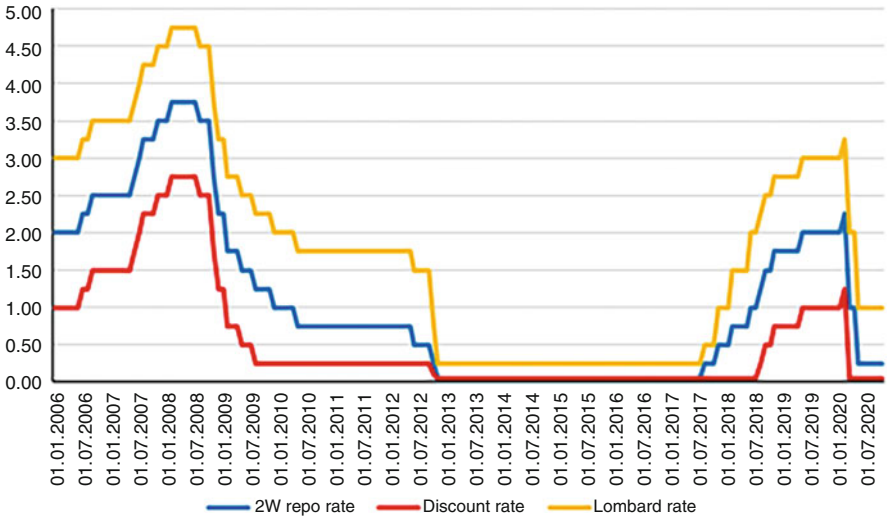

Fig. 9.4 CNB policy rates in 2006–2020. (Source: Authors based on CNB data)

9.4.1.2 Low Interest Rates (2012–2017)

The Czech banking sector is stable and well-capitalized and reports a liquidity surplus (CNB, 2017). In the years 2012–2017, the Czech National Bank (CNB) was keeping key interest rates technically at the zero level. The risk of early repayment of mortgages can be therefore significant, yet this risk is somewhat offset by long-term fixed mortgages granted before 2012, i.e., in periods of relatively higher interest rates. Moreover, this phenomenon can fully materialize in the next economic cycle.

CNB (2015) presented in its Financial Stability Report analysis of new mortgage loans, which distinguished between the totally new, refinanced, and refixed loans within the overall volume of new mortgage loans. It reported four groups of new mortgages as of March 1, 2015. First, 43% of the total volume was new loans. Second, 35% of the total loans were concluded with the new interest rate on the outstanding portion of the loan with the same financial service provider (refixed loans). Third, 14% of the total loans have been negotiated on the unpaid principal of the loan with the new provider (refinanced loans). Fourth, the remaining 8% share were mortgages with an increased principal. CNB (2015) further states that the largest increase in lending was recorded by small banks, namely, by more than 80%. It can be attributed to the fact that small banks most significantly compress the interest rate compared to other types of banks, and they were attracting clients to refinance their loans.

Moreover, CNB expected in 2017 that "Interest income can be expected to be adversely affected for some time to come by refixation and refinancing of mortgage loans, which will cause the average interest margin on the stock of such loans to move closer to that on new loans, which is significantly lower" (CNB, 2017).

9.4.1.3 Increasing Interest Rates (2017–2020)

The last considered period begins in 2017 when the CNB ended its unconventional monetary policy of exchange rate commitment and then started increasing its policy rates in a relatively fast way. This continued until the beginning of 2020 when CNB changed the course again due to the outbreak of the Covid-19 pandemic and decreased the policy rates in two steps to 0.25% from its peak of 2.25% in February 2020.

Due to the protracted Covid-19 pandemic situation continuing in 2021, the future development of monetary policy and market interest rates is rather uncertain. There are two main possible scenarios—that the rates will either remain low for a longer time (a situation resembling the period 2012–2017) or that the rates will start to go up similarly as in the period 2017–2020. Therefore, it is relevant to consider both periods as a model situation for both possible future scenarios.

9.4.2 Results of Theoretical Modeling in the 2011–2016 Period

9.4.2.1 Theoretical Modeling (Without Mortgage Prepayment)

Table 9.1 displays the banks' financing costs for the 2016–2021 period, assuming constant annual funding costs of 1.25% since 2016.[4] It is clear that the funding costs fall over time due to a decrease in market rates (from 1.73% at the end of 2016 to 1.25% at the end of 2021). In the calculations below, for simplicity, we assume a flat yield curve (for example, in 2012, the assumed interest rate for all maturities amounts to 2.0%, in 2013 to 1.75%, etc.). We also incorporate in the calculations a 5-year mortgage fixation, i.e., that only a portion of the banking portfolio is fixed each year. Specifically, 10% of mortgages are fixed in 2016, 20% of mortgages are fixed in 2017, and so on. Based on such an approximation, it is possible to obtain the average financing costs for the given years:

$$r_p = \sum_{t=1}^{T} r_t * w_t$$

where

r_p = average funding costs of the Bank in a given year
r_t = interest rate in a given year
w_t = weight in portfolio (share of fixed mortgages in a given year)
t = given year
T = end of the period

For the year rate r_p it holds that is equal to the weighted average of the applicable rate in the given year and its weight in the portfolio. After computations, the average rate $r_{2011\ -\ 2016}$ for the 2011–2016 period reached 1.73%:

$$\begin{aligned} r_{2011-2016} &= r_{2011} * w_{2011} + r_{2012} * w_{2012} + \ldots + r_{2016} * w_{2016} \\ &= 2.00\% * 10\% + 2.00\% * 20\% + \ldots + 1.25\% * 10\% = 1.73\% \end{aligned}$$

9.4.3 Theoretical Modeling (with Mortgage Prepayment)

In our models, three types of banks have been created, each with a different funding structure.[5] The benchmark is Bank 1, which cuts its financing costs from 2% in 2011

[4] These are real-time expert estimates.

[5] This is an illustrative example of an analysis of different levels of risk from different banks, which is reflected in the cost of financing. Assuming the same risk, banks should theoretically have the same financing costs (i.e. the possibility of financing for the same market yield curve). The only difference is in the yield curve (riskier banks should pay more upward on the credit margin). The increase and fall in interest rates on the market would then be the same for all banks, it would be a parallel shift in the yield curve.

Table 9.1 Funding costs of the Bank for the 2016–2021 period

Year	Interest rate	2016	2017	2018	2019	2020	2021
2011	2.00%	10%					
2012	2.00%	20%	10%				
2013	1.75%	20%	20%	10%			
2014	1.75%	20%	20%	20%	10%		
2015	1.50%	20%	20%	20%	20%	10%	
2016	1.25%	10%	20%	20%	20%	20%	10%
2017	1.25%		10%	20%	20%	20%	20%
2018	1.25%			10%	20%	20%	20%
2019	1.25%				10%	20%	20%
2020	1.25%					10%	20%
2021	1.25%						10%
Funding costs		**1.73%**	**1.58%**	**1.45%**	**1.35%**	**1.28%**	**1.25%**

Source: Authors
Note: We assume that interest rates reached the minimum in 2016 and will not decrease afterward

Table 9.2 Funding costs of Bank 1, Bank 2, and Bank 3 for the 2011–2016 period

	Funding costs		
Year	Bank 1	Bank 2	Bank 3
2011	2.00%	3.00%	4.00%
2012	2.00%	3.00%	4.00%
2013	1.75%	2.63%	3.50%
2014	1.75%	2.63%	3.50%
2015	1.50%	2.25%	3.00%
2016	1.25%	1.88%	2.50%

Source: Authors

to 1.25% in 2016. Bank 2 in this period reports 1.5 times the rates of Bank 1, while Bank 3 has its funding at 2 times the rates of Bank 1 (Table 9.2).

Table 9.3 summarizes the results of modeling the impact of early repayment of mortgages on Bank 1 income and a 20% share of prepaid mortgages,[6] according to which the accumulated loss on the Bank's interest income would reach 0.27% at the end of 2021.

Table 9.4 shows the results of modeling the impact of early repayment of mortgages on Bank 3's income and a 20% share of prepaid mortgages. It displays that the cumulative loss on Bank 3's interest income would reach 0.53% at the end of 2021 (0.16% by 2017), which may be a significant loss for this type of bank.[7]

[6]The Czech consumer credit law approved in 2016 allows the client to prepay up to 25% of the mortgage a year free of charge. However, we do not expect that the 25% ratio would have materialized, so provide a robust scenario analysis for 10%, 20%, and 50% shares of prepaid mortgages.

[7]For comparison, Wüstenrot Mortgage Bank a.s., a small Czech bank, reported an overall interest margin of 1.79% as of December 31, 2014. The computed 0.53% loss would represent 29.6% of the 1.79% total margin. Overall, the net interest rate margin of the Czech banking sector fell down from 2.48% as of 31 December 2008 to 1.53% as of 30 September 2020 (i.e. a 37.3% decrease, see Fig. 9.5).

Table 9.3 Impact of early repayment of mortgages on the Bank's income (Bank 1, 20% share of prepaid mortgages)

Bank 1						Calculated loss					
Year	Interest rate	Structure of funding costs in 2016	Ratio of prepaid mortgages	Volume	Difference	2016	2017	2018	2019	2020	2021
2011	2.00%	10%	20%	2.00%	0.75%	0.02%					
2012	2.00%	20%	20%	4.00%	0.75%	0.03%	0.03%				
2013	1.75%	20%	20%	4.00%	0.50%	0.02%	0.02%	0.02%			
2014	1.75%	20%	20%	4.00%	0.50%	0.02%	0.02%	0.02%	0.02%		
2015	1.50%	20%	20%	4.00%	0.25%	0.01%	0.01%	0.01%	0.01%	0.01%	
2016	1.25%	10%	20%	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loss in a given year						**0.10%**	**0.08%**	**0.05%**	**0.03%**	**0.01%**	**0.00%**
Cumulative loss for the whole period						**0.10%**	**0.18%**	**0.23%**	**0.26%**	**0.27%**	**0.27%**

Source: Authors

Table 9.4 Impact of early repayment of mortgages on the Bank's income (Bank 3, 20% share of prepaid mortgages)

Bank 3						Calculated loss					
Year	Interest rate	Structure of funding costs in 2016	Ratio of prepaid mortgages	Volume	Difference	2016	2017	2018	2019	2020	2021
2011	4.00%	10%	20%	2.00%	1.50%	0.03%					
2012	4.00%	20%	20%	4.00%	1.50%	0.06%	0.06%				
2013	3.50%	20%	20%	4.00%	1.00%	0.04%	0.04%	0.04%			
2014	3.50%	20%	20%	4.00%	1.00%	0.04%	0.04%	0.04%	0.04%		
2015	3.00%	20%	20%	4.00%	0.50%	0.02%	0.02%	0.02%	0.02%	0.02%	
2016	2.50%	10%	20%	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loss in a given year						**0.19%**	**0.16%**	**0.10%**	**0.06%**	**0.02%**	**0.00%**
Cumulative loss for the whole period						**0.19%**	**0.35%**	**0.45%**	**0.51%**	**0.53%**	**0.53%**

Source: Authors

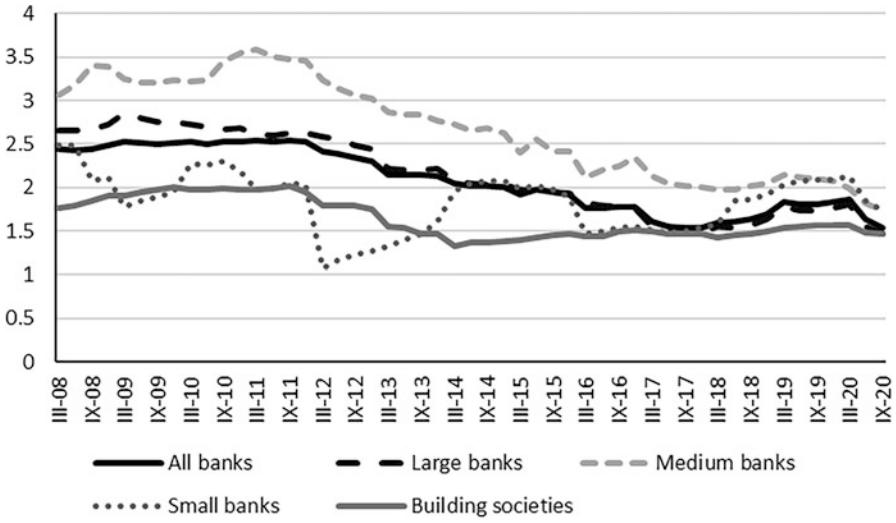

Fig. 9.5 Quarterly development of net interest margin of Czech banks (%). (Source: Authors based on CNB data)

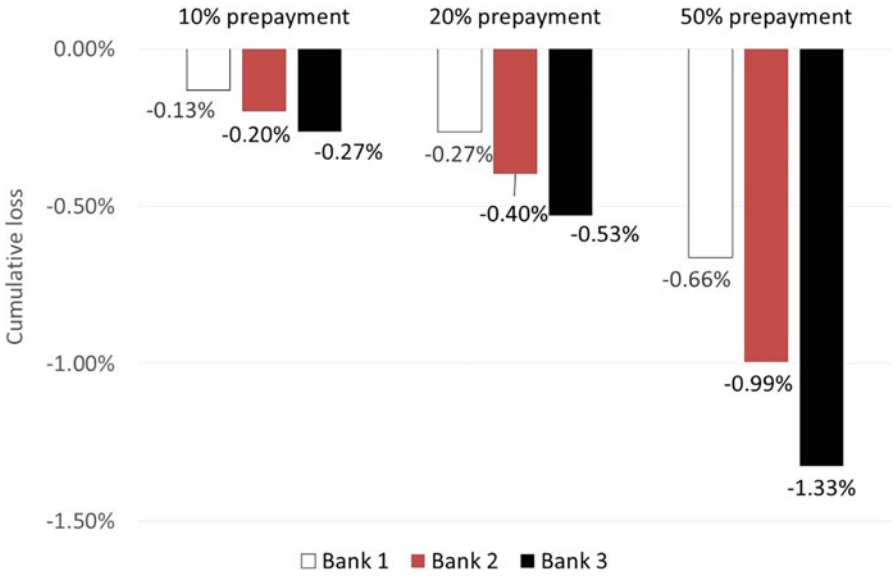

Fig. 9.6 The impact of early repayment of mortgages on the income of Banks 1, 2, and 3 for different ratios of early repayments (10%, 20%, 50%) in the period 2016–2021. (Source: Authors)

Figure 9.6 illustrates the impact of early repayment of mortgages on the returns of Banks 1, 2, and 3 for the various proportions of early repayment mortgages (10%, 20%, 50%) for the period 2016–2021. It is clear that different types of banks have different impacts, which are generally linear. The results show that, in the extreme

case, Bank 3, at 50% early repayment, could accumulate a loss in interest rate margin of 1.33% in the period 2016–2021.

9.4.3.1 Empirical Modeling (Without Mortgage Prepayment)

The above theoretical modeling can be verified by empirical analysis. Looking at the history of interest rates in the Czech Republic over the period 2000–2020, we find that the largest drops in rates were recorded in the 2001–2006 period, when the 1-year Prague Interbank Offered Rate (PRIBOR) dropped from 5.85% to 2.55% (Table 9.5), and in 2008–2013, when the 1Y PRIBOR dropped from 4.24% to 0.87% (Table 9.6). On the other hand, in the period 2017–2020, the 1Y PRIBOR experienced a period of relatively fast increase (Table 9.8). In such a case, the banks could theoretically gain from prepayments by reinvesting the cash from prepaid mortgages into new mortgages with higher rates. On the other hand, these gains may be limited by lower incentives for the clients to repay their mortgages.

By applying the abovementioned market rates and assuming a 20% prepayment of mortgages, it can be calculated that the total cumulative expected loss would be 0.24% in the period 2001–2006 (Table 9.5) and, respectively, 0.78% in the 2008–2013 period (Table 9.6).

In Table 9.7, we present results for the period 2011–2016, i.e., a period in which the rates were already very low and decreased only modestly toward the zero lower bound. Finally, Table 9.8 shows results for the period 2016–2020, during which the rates started to rise. Assuming a constant rate of prepayment, we can see that in such a case, the cumulative expected loss becomes negative; that is, the bank experiences a gain in margin of 0.65 percentage points.

9.5 Conclusion

In this paper, we deal with prepayment risks in banking and provide empirical evidence from the Czech banking sector. The prepayment risk of a loan represents an embedded option for a client to refinance his mortgage for a lower interest rate. The client may have an incentive to repay the remaining amount of the loan before its maturity, especially in case he can refinance the loan with a new loan with a lower interest rate. Conversely, it holds that the client's profit means a loss to the bank as a mortgage provider. In the empirical part, our analysis quantifies the impact of early repayment of the mortgage on the balance sheets of different types of banks, which differ in the structure of their financing. In particular, the effect of prepaying mortgages on the interest margins of model banks was examined. Our results show that this effect could become significant, especially in the decreasing interest rate environment, when the clients have incentives to repay their existing mortgage with a higher rate with a new one with a lower rate. On the contrary, in the period of increasing interest rates, the bank could gain on the prepayments if they are able to

Table 9.5 Loss of bank income based on actual 1Y PRIBOR market rates in 2001–2006

						Calculated loss					
Year	Market interest rate (1Y PRIBOR)	Structure of funding costs in 2016	Ratio of prepaid mortgages	Volume	Difference	2006	2007	2008	2009	2010	2011
2001	5.85%	10%	20%	2.00%	3.30%	0.07%					
2002	4.47%	20%	20%	4.00%	1.92%	0.08%	0.08%				
2003	2.54%	20%	20%	4.00%	−0.01%	0.00%	0.00%	0.00%			
2004	2.35%	20%	20%	4.00%	−0.20%	−0.01%	−0.01%	−0.01%	−0.01%		
2005	2.81%	20%	20%	4.00%	0.26%	0.01%	0.01%	0.01%	0.01%	0.01%	
2006	2.55%	10%	20%	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loss in a given year						**0.14%**	**0.08%**	**0.00%**	**0.00%**	**0.01%**	**0.00%**
Cumulative loss for the whole period						**0.14%**	**0.22%**	**0.23%**	**0.23%**	**0.24%**	**0.24%**

Source: Authors

Table 9.6 Loss of bank income based on real 1Y PRIBOR market rates in 2008–2013

						Calculated loss					
Year	Market interest rate (1Y PRIBOR)	Structure of funding costs in 2016	Ratio of prepaid mortgages	Volume	Difference	2013	2014	2015	2016	2017	2018
2008	4.24%	10%	20%	2.00%	3.37%	0.07%					
2009	3.89%	20%	20%	4.00%	3.02%	0.12%	0.12%				
2010	2.13%	20%	20%	4.00%	1.26%	0.05%	0.05%	0.05%			
2011	1.80%	20%	20%	4.00%	0.93%	0.04%	0.04%	0.04%	0.04%		
2012	1.72%	20%	20%	4.00%	0.85%	0.03%	0.03%	0.03%	0.03%	0.03%	
2013	0.87%	10%	20%	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loss in a given year						**0.31%**	**0.24%**	**0.12%**	**0.07%**	**0.03%**	**0.00%**
Cumulative loss for the whole period						**0.31%**	**0.55%**	**0.67%**	**0.75%**	**0.78%**	**0.78%**

Source: Authors

Table 9.7 Loss of bank income based on real 1Y PRIBOR market rates in 2011–2016

						Calculated loss					
Year	Market interest rate (1Y PRIBOR)	Structure of funding costs in 2016	Ratio of prepaid mortgages	Volume	Difference	2016	2017	2018	2019	2020	2021
2011	1.80%	10%	20%	2.00%	1.34%	0.03%					
2012	1.72%	20%	20%	4.00%	1.26%	0.05%	0.05%				
2013	0.87%	20%	20%	4.00%	0.41%	0.02%	0.02%	0.02%			
2014	0.60%	20%	20%	4.00%	0.14%	0.01%	0.01%	0.01%	0.01%		
2015	0.51%	20%	20%	4.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	
2016	0.46%	10%	20%	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loss in a given year						**0.10%**	**0.07%**	**0.02%**	**0.01%**	**0.00%**	**0.00%**
Cumulative loss for the whole period						**0.10%**	**0.18%**	**0.20%**	**0.21%**	**0.21%**	**0.21%**

Source: Authors

Table 9.8 Loss of bank income based on real 1Y PRIBOR market rates in 2015–2020

						Calculated loss					
Year	Market interest rate (1Y PRIBOR)	Structure of funding costs in 2016	Ratio of prepaid mortgages	Volume	Difference	2020	2021	2022	2023	2024	2025
2015	0.51%	10%	20%	2.00%	−1.76%	−0.04%					
2016	0.46%	20%	20%	4.00%	−1.81%	−0.07%	−0.07%				
2017	0.44%	20%	20%	4.00%	−1.83%	−0.07%	−0.07%	−0.07%			
2018	0.97%	20%	20%	4.00%	−1.30%	−0.05%	−0.05%	−0.05%	−0.05%		
2019	2.07%	20%	20%	4.00%	−0.21%	−0.01%	−0.01%	−0.01%	−0.01%	−0.01%	
2020	2.27%	10%	20%	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loss in a given year						**−0.24%**	**−0.21%**	**−0.13%**	**−0.06%**	**−0.01%**	**0.00%**
Cumulative loss for the whole period						**−0.24%**	**−0.45%**	**−0.58%**	**−0.64%**	**−0.65%**	**-0.65%**

Source: Authors

provide new loans for the higher rates, but at the same time, the prepayment risk decreases due to lower incentives for clients to prepay.

The prepayment risk was strengthened by the Czech consumer credit law approved in 2016, which allows the client to prepay up to 25% of the mortgage a year free of charge. Based on our model, we compute the impact of early repayment of the mortgage on the balance sheets of three different types of banks. The results of theoretical modeling have shown that these risks forced by banks might have a substantial effect, and they are likely to be one of the factors contributing to the decreasing net interest margin of the Czech banking sector in the 2019–2020 period. However, the prepayment risk in the Czech Republic decreased when interest rates started to rise in 2021.

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