Prepayment Risk in Banking: Empirical Evidence from the Czech Republic

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April 2018

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Abstract

This paper deals with prepayment risk 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 their 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 balance sheets of three different types of banks, which differ in the structure of their financing. In particular, we examine the negative effect of prepaid mortgages on the interest margins of these banks. The results of models have shown that these prepayments risks are not only theoretical, but they are actually reflected in the decreasing net interest margin of the Czech banking sector.

Key words: asset liability management, bank, interest rate, mortgage, prepayment risk

JEL codes: G21, G32

1. Introduction

Our analysis 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 issuing Czech banks. This topic has become more relevant during the recent low-interest rate environment. The remainder of the paper is organised as follows: in section 2 we discuss key basic terms (embedded options of a bond and of a bank loan) needed for our research. Section 3 presents the methodology applied (case study on interest rate risk of a bank and the net present value concept of a banks' total loss). In section 4, we undertake an empirical analysis and compute the impact of early repayment of the mortgage on the balance sheets of three different types of banks. The last section concludes the paper.

2. Theoretical part

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 an 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 instrument 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 the price loss that may arise from the 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 pre-agreed upon price (serving as a defacto ceiling on the price of the bond). This fact favours the borrower in the event of a fall in market interest rates, because it gives him the opportunity to refinance debt under more favourable 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 primary on the impact of the call option, which favours the borrower during decreasing market interest rates and it 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 (2014).

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 exercise 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 interest rate position of the bank as discussed later.

Hayre and Young (2008) highlights 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 case of destruction of the house by a natural disaster). However, it is necessary to distinguish the different sensitivity of the client´s willingness to prepay a mortgage. While interest rates are decreasing, the sensitivity is high. In contrary, the sensitivity can be quite minimal in case of solving the life situation such as divorce or settlement of inheritance.

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.

3.1 Case study on interest rate risk of a bank

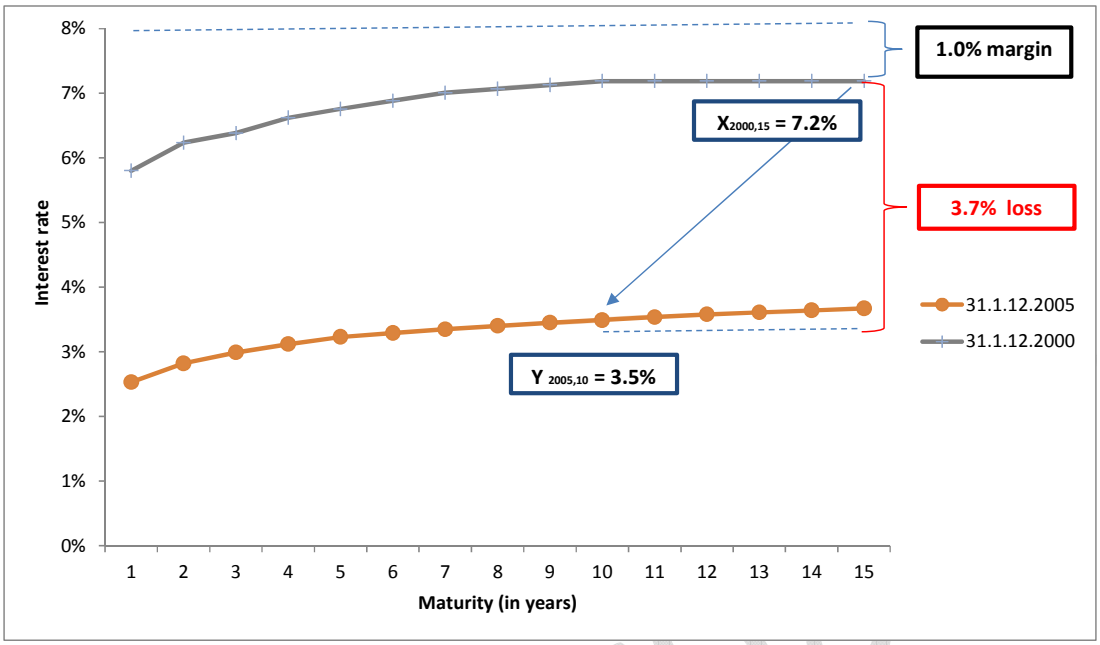
The impact of early repayment of the mortgage can be illustrated by the bank's asset-liability-department (ALM) problem. For example, for a mortgage with a 5-year fixed term, the bank would need to offset its risk by finding adequate resources, such as an interest rate swap with the same maturity (a 5-year bank´s 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 at a low-interest rate environment. For simplicity, let's 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. The figure below illustrates this interest rate risk based on the real yield curves in the Czech Republic valid as of 31 December 2000 and 31 December 2015. Let´s suppose a bank (denoted as „the Bank") entered a 15-year fixed rate swap on 31 December 2000 with a fixed rate of 7.2%[1] to finance a mortgage on that day with a 1%[2] margin (i.e. a total rate of 8.2%). However, five 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 swap for the remaining 10 years, implying a loss of 3.7%[3] for the period 2006-2015.

[1] It means that Bank paid a variable rate (based on 1-month Prague Interbank Offered Rate (PRIBOR) for instance).

[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) spread rate- is equal to zero).

[3] 3.7 % = 7.2% - 3.5% (total loss = funding costs – a new swap interest rate).

Figure 1: Interest rate risk of the Bank as of 31 December 2005



Source: Author

Note: Loss from funding =X(2000,15)−Y(2005,15)= 7.2% - 3.5% = 3.7 %, where $X_{(2000,15)}$=15-year interest rate in 2000 and $Y_{(2005,15)}$=10-year interest rate in 2005

3.2 The net present value of 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 = cash flow in given year
r_t = interest rate in 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 be generated over the entire period, with the interest rate corresponding to the yield curve as of 31 December 2005 (see also Figure 1):

$$Loss = \frac{CF_1}{(1+r_1)^1} + \frac{CF_2}{(1+r_2)^2} + \cdots + \frac{CF_{10}}{(1+r_{10})^{10}} =$$

$$= \frac{37\,000}{(1+2.5\%)^1} + \frac{37\,000}{(1+2.8\%)^2} + \cdots + \frac{37\,000}{(1+3.5\%)^{10}} = 310{,}900$$

The loss can be understood as a bank's cost that a counterparty (such as a corporate client or other bank) 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 31 December 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.

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 will use real interbank interest rates for the 2006-2013 period based on 1-year Prague Interbank Offered Rate (PRIBOR). Second, we estimate the impact of early paid mortgages on the investigated banks for the 2016-2021 period.

4.1 Situation in the Czech banking sector

The Czech banking sector is stable, well-capitalized and reports a liquidity surplus (CNB, 2017)[4]. In the 2012-2017 the Czech National Bank (CNB) was keeping key interest rates technically at the zero level.[5] The risk of early repayment of mortgages can be therefore significant yet this risk is somewhat offset by long-term fixed mortgages granted before

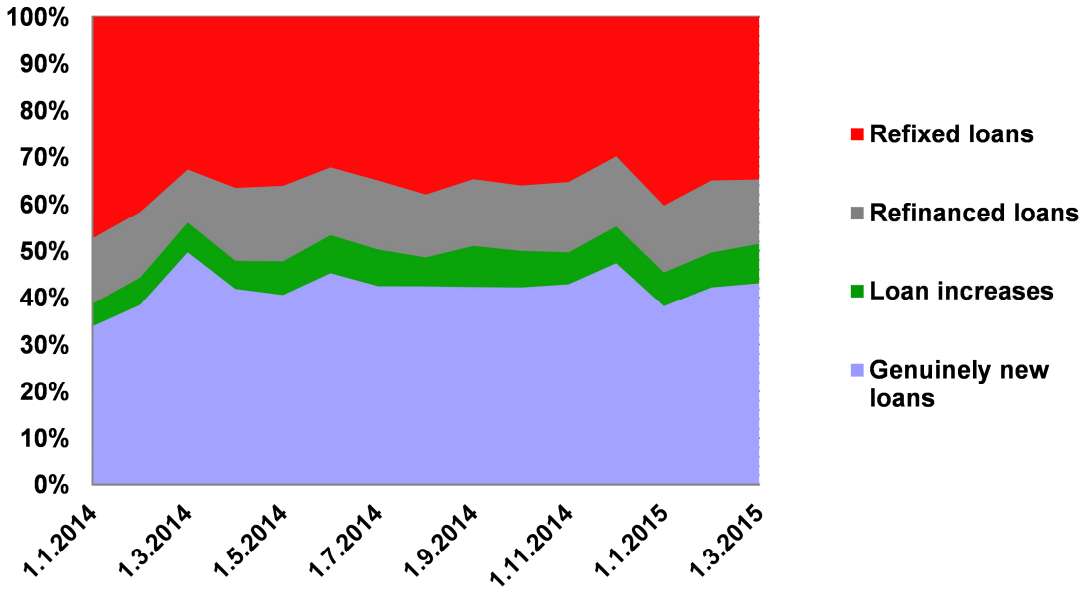
[4] For more details on the Czech banking sector and related risk management practices we refer to, for example, Černohorská et al. (2017), Stádník (2014) or Witzany (2017).

5 To be specific, the CNB set a 2-week repo rate at 0.05% in November 2012 and kept it until August 2017, when the rate was raised to 0.25%. In February 2018, the CNB increase the 2-week repo rate further to 0.50%, what indicates tightening monetary policy.

2012, i.e. in periods of relatively higher interest rates. Moreover, this phenomenon can fully materialize in the next economic cycle.

CNB (2015) presented an analysis of new mortgage loans, which distinguished between the totally new, refinanced and refixed loans within the overall volume of new mortgage loans. Figure 2 reports three four groups of new mortgages as of 1 March 2015. First, 43% of the total volume were new loans. Second, 35% of 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, 15% of total loans have been negotiated on the unpaid principal of the loan with the new provider (refinanced loans). Fourth, the remaining 7% share were mortgages with 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.

Figure 2: Structure of new mortgage loans in the Czech Republic as of 31 March 2015



Source: CNB (2015)

4.2 Results of theoretical modelling in the 2011-2016 period

4.2.1 Theoretical modelling (without mortgage prepayment)

Table 1 displays the bank's financing costs for the 2016-2021 period, assuming constant annual funding costs of 1.25% since 2016.[6] 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 2.0%, in 2013 at 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 in each year. Specifically, in 2016, 10% of mortgages are fixed, 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:

[6] These are real-time expert estimates.

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

where
r_p = average funding costs of the Bank in given year
r_t = interest rate in given year
w_t = weight in portfolio (share of fixed mortgages in 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%:

$$r_{2011-2016} = r_{2011} * w_{2011} + r_{2012} * w_{2012} + \cdots + r_{2016} * w_{2016} =$$

$$= 2.00\% * 10\% + 2.00\%* 20\% +...+ 1.25\ \%*10\% = 1.73\ \%$$

Table 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: Author
Note: We assume that interest rates reached the minimum in 2016 and will not decrease afterwards.

4.2.2 Theoretical modelling (with mortgage prepayment)

In our models, three types of banks have been created, each with a different funding structure.[7] Benchmark is Bank 1, which cuts financing costs from 2.00% in 2011 to 1.25%

[7] 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

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 2).

Table 2: Funding costs of Bank 1, Bank 2 and Bank 3 for the 2016-2021 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: Author

Table 3 summarizes the results of modelling the impact of early repayment of mortgages on Bank 1 income and a 20% share of prepaid mortgages[8], according to which the accumulated loss on the Bank's interest income would reach 0.27% at the end of 2021.

Table 3: Impact of early repayment of mortgages on 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: Author

Table 4 shows the results of modelling the impact of early repayment of mortgages on Bank 3 income and a 20% share of prepaid mortgages. It displays that the cumulative loss on the

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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.

[8] 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 don't expect that the 25% ratio would have materialized, so provide a robust scenario analysis for 10%, 20% and 50 % shares of prepaid mortgages.

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. [9]

Table 4: Impact of early repayment of mortgages on Bank's income (Bank 3, 20% share of prepaid mortgages)

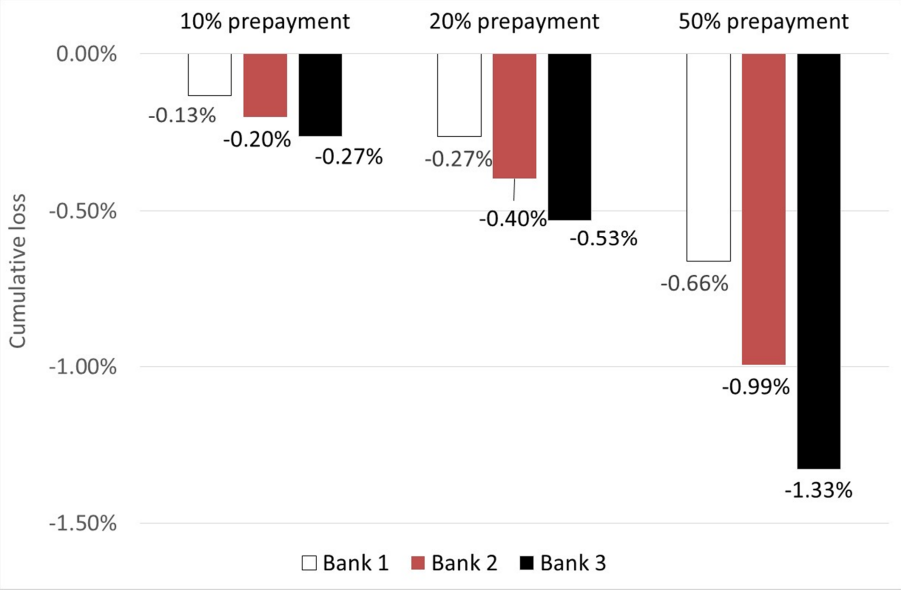
Bank 3						Calculated loss					
Year	Interest rate	Structure of funding costs in 2016	Ratio of prepaid mortgages	Volume	Difference	2016	2017	2018	2019	2020	2021
2011	4.00%	10%	20%	2.00%	1.50%	0.03%					
2012	4.00%	20%	20%	4.00%	1.50%	0.06%	0.06%				
2013	3.50%	20%	20%	4.00%	1.00%	0.04%	0.04%	0.04%			
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

Figure 3 illustrates the impact of early repayment of mortgages on Bank 1, 2 and 3 returns 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 that 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] 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 2017 (i.e. a 37.3% decrease).

Figure 3: The impact of early repayment of mortgages on Banks 1, 2 and 3 income for different ratio of early repayments (10%, 20%, 50%) in the period 2016-2021



Source: Author

4.2.3 Empirical modelling (with mortgage prepayment)

The above theoretical modelling can be verified by an empirical analysis. Looking at the history of interest rates in the Czech Republic over the period 2000-2015, we find that the largest drops in rates were recorded in the 2001-2006 period when the 1Y PRIBOR dropped from 5.85% to 2.55% (Table 5) and in 2008-2013, where 1Y PRIBOR dropped from 4.24% to 0.87% (Table 6).

Table 5: Loss of bank income based on real 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: Author

By applying the above-mentioned 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 2006-2011 (Table 5) and respectively 0.78% in the 2013-2018 period (Table 6).

Table 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: Author

5. Conclusion

In this paper we deal with prepayment risk 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 repays the remaining amount of the loan before its maturity, which is better for him because of 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. This effect can be expected to be significant because the Czech consumer credit law was approved in 2016, what allows the client to prepay up to 25% of the mortgage a year free of charge. Based on our modelling, we compute the impact of early repayment of the mortgage on the balance sheets of three different types of banks. The results of theoretical modelling have shown that these risks forced by banks are not only theoretical, but they are actually reflected in the decreasing net interest margin of the Czech banking sector.

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Acknowledgement
This research was supported by the Czech Science Foundation (Projects No. 16-21506S and 17-02509S) and University of Economics in Prague (Project No. VŠE IP100040).