



Lion's Den 2021

Loan Prepayments

Adam Chwila, Market Risk Management Department

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thinkforward



Introduction

- Working in ING Bank Śląski ~ 3 years
- Started working at ING during last year of graduate studies
- Main responsibility: Prepayment modeling
- Studied Analityka Gospodarcza (Quantitative Methods for Economics and Business) at University of Economics in Katowice



Agenda

- What are the loan prepayments
- Modelling approaches
- Why do we need prepayment forecasts
- Summary & conclusions

What are the loan prepayments

Loan prepayment

- An earlier repayment than specified in the loan installment schedule
- It can concern the whole remaining loan volume or only part of it

Example

- Client has taken loan equal to 10 000
- In the example we focus only on the monthly repayment of the capital (we do not focus on the every-month interests)
- Client has agreed to the repayment schedule that involves paying back 1 000 every month for the next 10 months

Loan prepayment example

- The Bank **expects** to get 1 000 every month

Time of repayment	Amount
2021-06	1 000
2021-07	1 000
2021-08	1 000
2021-09	1 000
2021-10	1 000
2021-11	1 000
2021-12	1 000
2022-01	1 000
2022-02	1 000
2022-03	1 000

However client fully prepays his loan after 5 months: firstly he pays back scheduled 1 000 and then extra 5 000 volume is prepaid

- However, client **behaves** differently

Time of repayment	Amount
2021-06	1 000
2021-07	1 000
2021-08	1 000
2021-09	1 000
2021-10	6 000
2021-11	-
2021-12	-
2022-01	-
2022-02	-
2022-03	-

The consequences of prepayments for the borrower

- The **amount of interest** that the borrower pays is **lower**, because the money was borrowed for a shorter period than originally planned in loan agreement

If the client partially prepays his loan, additionally:

- The **volume of future installments is reduced**, but the repay periods are the same or
- The loan **period is shortened** while maintaining the same amount of installments

Prepaying lowers the overall costs of the loan

Full prepayment example

➤ Interests: 150

Time of repayment	Amount
2021-06	1 000
2021-07	1 000
2021-08	1 000
2021-09	1 000
2021-10	1 000
2021-11	1 000
2021-12	1 000
2022-01	1 000
2022-02	1 000
2022-03	1 000



➤ Interests: 130

Time of repayment	Amount
2021-06	1 000
2021-07	1 000
2021-08	1 000
2021-09	1 000
2021-10	6 000
2021-11	-
2021-12	-
2022-01	-
2022-02	-
2022-03	-

5 000 repaid after 5 months
instead of 1 000 after 6, 7, 8, 9
and 10 months



Cheaper loan

Partial prepayment example

➤ Interests: 150

Time of repayment	Amount
2021-06	1 000
2021-07	1 000
2021-08	1 000
2021-09	1 000
2021-10	1 000
2021-11	1 000
2021-12	1 000
2022-01	1 000
2022-02	1 000
2022-03	1 000



➤ Interests: 140

Time of repayment	Amount
2021-06	1 000
2021-07	1 000
2021-08	1 000
2021-09	1 000
2021-10	4 000
2021-11	1 000
2021-12	1 000

OR

➤ Interests: 142

Time of repayment	Amount
2021-06	1 000
2021-07	1 000
2021-08	1 000
2021-09	1 000
2021-10	4 000
2021-11	400
2021-12	400
2022-01	400
2022-02	400
2022-03	400

The consequences of prepayments for the Bank

- **Decrease in profit**
- The customer who prepaid the loan paid a total amount of interest lower than it resulted from the original loan agreement
- **Faster** than specified in the repayment schedules **access to the funds**
- That additional **funds have to be reinvested** by the Bank

Prepayment compensation fees

- The customer's profit on loan prepayment may be reduced by the compensation fee
- Fee is intended to reduce the Bank's loss
- Fee practically never fully compensates the Bank's loss
- Most of the times the loan prepayment is not a subject of compensation fee at all

Original schedule

- Interests: 150



Prepayment

- Interests: 140



Compensation fee

- Interests: 145

Modeling approaches

Modeling prepaid volume vs prepayment rate

- The first basic approach assumes **modeling prepaid volume**
- The second approach assumes **modeling prepayment ratio** defined as:

$$PR_t = \frac{P_t}{N_t - R_t}$$

PR_t – monthly prepayment rate at month t

P_t – amount prepaid at month t

N_t – outstanding national from the beginning of month t

R_t – scheduled repayment at time t

The final approach should be considered by the reseacher

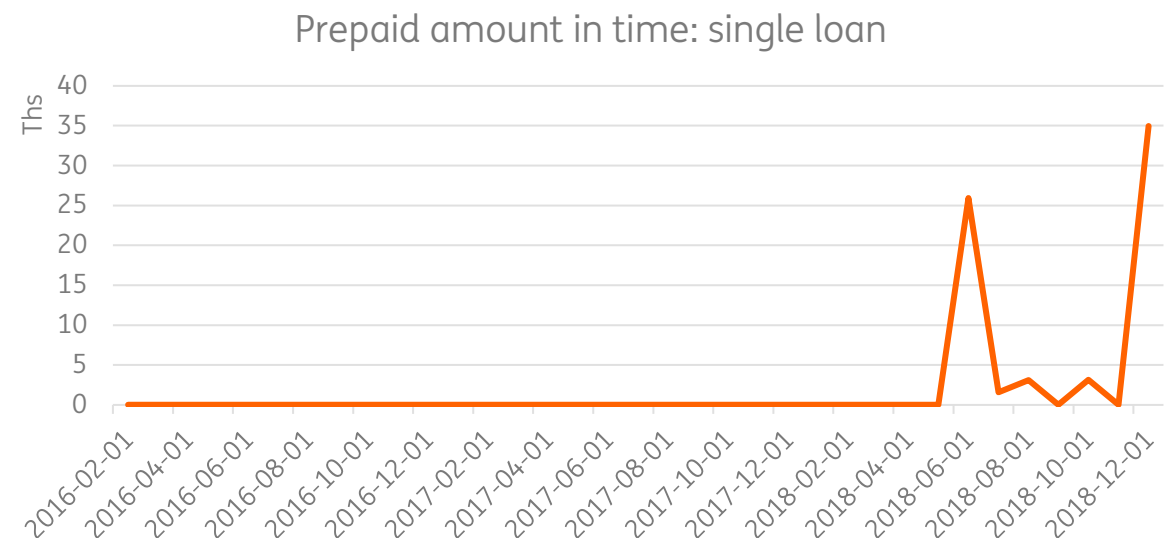
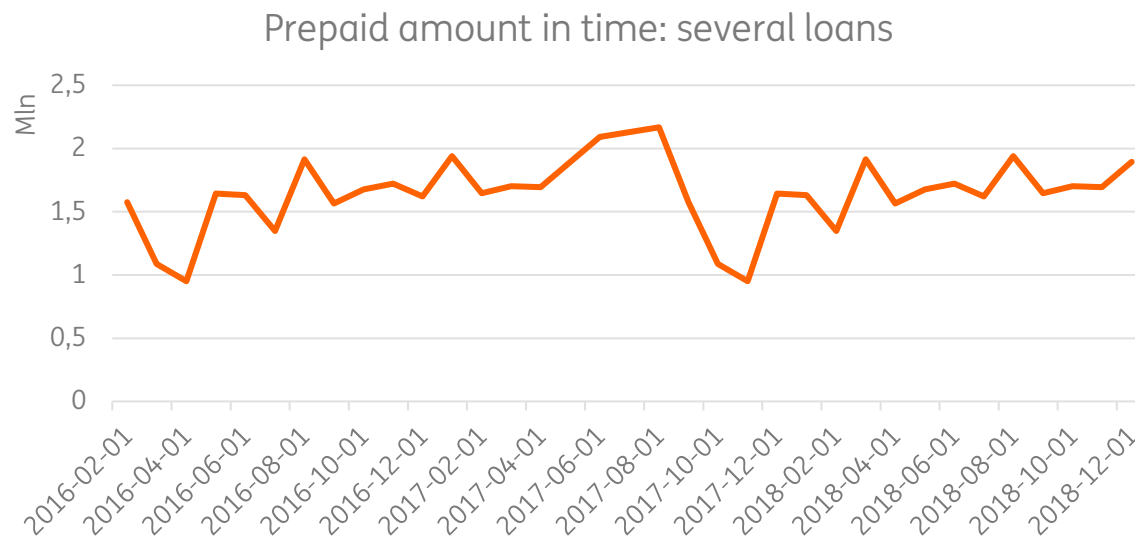
Modeling prepaid volume vs prepayment rate

- In October 2021 client firstly repays the scheduled 1 000 and then prepays 3 000
- The prepayment rate is calculated as the ratio of prepaid volume and amount left to be repaid accordingly to the schedule

Time of repayment	Original schedule	Real schedule	Prepaid	Prepayment rate
2021-06	1 000	1 000	0	0%
2021-07	1 000	1 000	0	0%
2021-08	1 000	1 000	0	0%
2021-09	1 000	1 000	0	0%
2021-10	1 000	4 000	3 000	60%
2021-11	1 000	400	0	0%
2021-12	1 000	400	0	0%
2022-01	1 000	400	0	0%
2022-02	1 000	400	0	0%
2022-03	1 000	400	0	0%

Modeling single loans vs aggregated portfolio

- **Single loans modeling:** state of each contract for each month is considered as separate record
- **Aggregated modeling:** several loans aggregated into one record based on some characteristics



Regression and segmentation

- Two modeling **approaches** are usually combined with each other
- **Regression:** fitting a statistical function
- **Segmentation:** the division of the loans into a number of homogeneous clusters due to additional variables, e.g., a cluster in which the customer's age is below 40 and a cluster in which there are customers of 40 or more years of age. Separate regression functions are then determined for separated clusters
- A portfolio is a group of loans that are homogenous (single segment)

Additional variables

- During prepayment modelling the usage of many additional variables may be considered, for segmentation as well as for regression

The exemplary additional variables could be:

- Age of the loan in years
- Time remaining to maturity
- Age of the client
- Month of the prepayment
- The outstanding volume left to be repaid
- Many more: market or contract characteristics

Client behavior: financial incentive to prepay

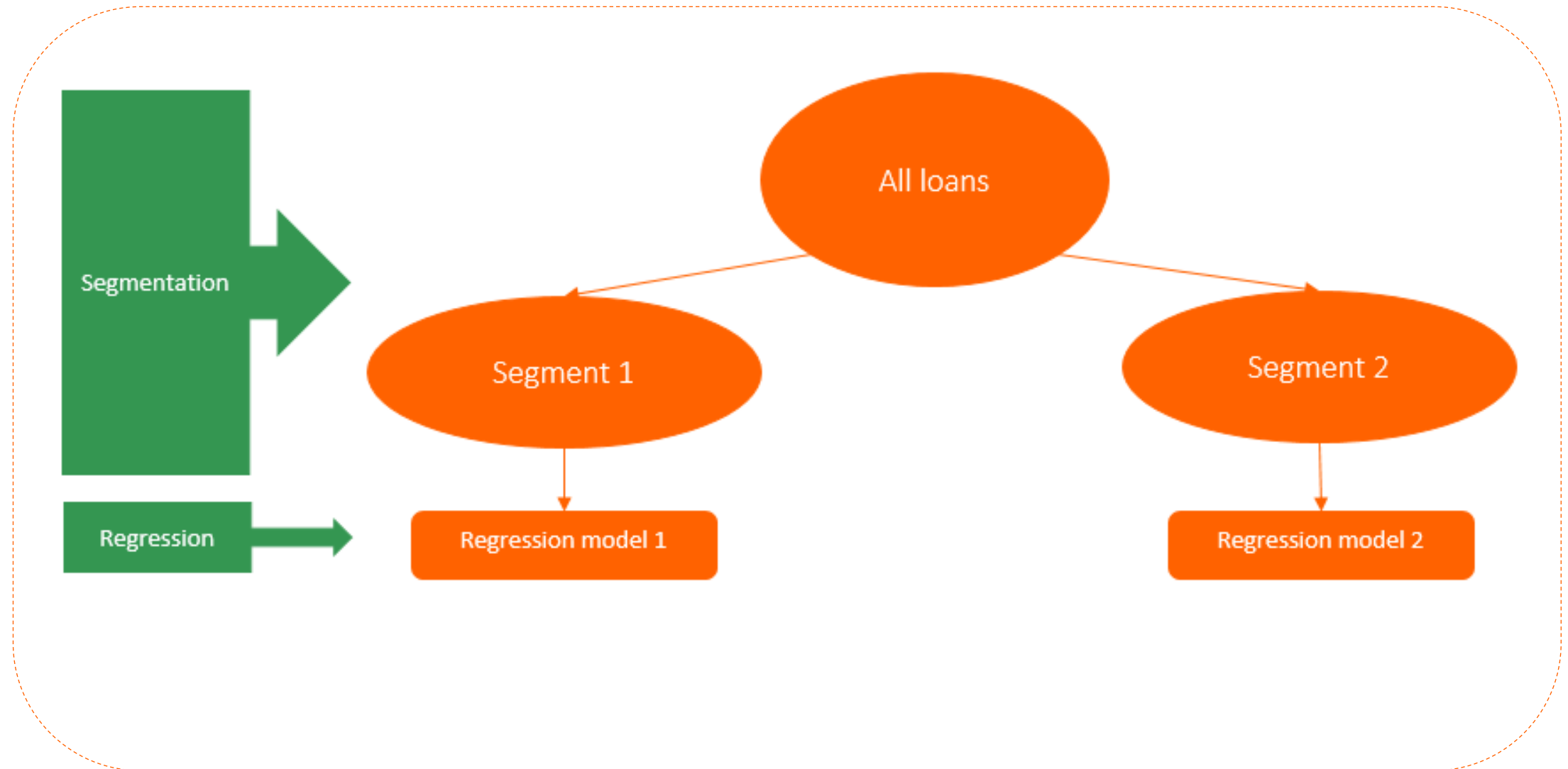
- A customer with free cash resources may wonder whether he will achieve a higher benefit by prepaying a loan or investing his funds in a different way
- **Financial incentive is based on the client's loan price and the current price of the similar products on the market**
- Client may want to prepay a loan in order to take the new one but with the cheaper price
- Prices of the loans are dependent on the current market conditions

Additional variables

An important issue regarding usage of additional variables is that in order to make forecasts of future prepayment levels, the future values of additional variables have to be:

- Known (i.e. age of the loan can be computer for any future time horizon)
- Estimated by other models (i.e. future market rates)

Exemplary modeling approach



Metrics that helps assess the accuracy

- The goal of modeling is to have **low error of predictions**
- The **accuracy** of the chosen approaches can be tested on a **loan or portfolio level**
- There is a lot of possible approaches: RMSE, MAE, WMAPE e.t.c.
- For example in case of the whole portfolio, the adjusted RMSE can be considered

Metrics that helps assess the accuracy: adjusted RMSE

➤
$$RPR_n = \frac{\sum_{i(n)} Vol_{i(n)} \cdot RPR_{i(n)}}{\sum_{i(n)} Vol_{i(n)}}$$

➤
$$MPR_n = \frac{\sum_{i(n)} Vol_{i(n)} \cdot MPR_{i(n)}}{\sum_{i(n)} Vol_{i(n)}}$$

➤
$$Vol_n = \sum_{i(n)} Vol_{i(n)}$$

➤
$$adjusted\ RMSE = \sqrt{\frac{\sum_{n=1}^N Vol_n \cdot (RPR_n - MPR_n)^2}{\sum_{n=1}^N Vol_n}}$$

RPR_i is the observed realized monthly prepayment rate for bucket i ,

MPR_i is the modelled monthly prepayment rate for bucket i ,

Vol_i is the total notional in bucket i

N is the total number of months

Some remarks regarding the chosen modeling approach

- The chosen approach regarding the division of loans into segments should be always supported **by analysis and substantive explanation**
- The inclusion of the additional variables should be explained and supported by qualitative and quantitative analysis
- Sometimes the inclusion of an additional variable allows to slightly more accurate predictions, but the qualitative analysis lacks in explanation
- Expert adjustments may also be included in the modeling process if well explained

Some remarks regarding the chosen modeling approach

- If we use additional variables for which future values have to be predicted by other models, the accuracy of predictions will be also dependent on the accuracy of other models
- In case of risk modelling the complex black-box models are not recommended, because their usage is hard to explain to the banking regulators
- **In case risk modeling interpretability of the results is very important**

Sometimes less is more

Why do we need prepayment forecasts

The goals of prepayment modelling

- Bank is more robust to unexpected losses from prepayments, because of more accurate hedges
- Loan prepayments are modeled in order to make the **loan repayment schedules more realistic**
- To do so, the forecasted level of prepayments for a given month is added to the monthly repayments resulting from the planned schedule
- The modelled **schedules are constructed on the whole portfolio level**

Exemplary modelled repayment schedule

Date	Planned repayments	Outstanding volume left to be repayed (planned schedule)	Modelled repayment (planned repayments + modelled prepayments)	Outstanding volume left to be repayed (modelled schedule)
		176 000		176 000
2020-01	10 000	166 000	11 660	164 340
2020-02	10 000	156 000	11 444	152 896
2020-03	10 000	146 000	11 232	141 664
2020-04	10 000	136 000	11 023	130 641
2020-05	10 000	126 000	10 816	119 825
2020-06	10 000	116 000	10 613	109 212
2020-07	10 000	106 000	10 413	98 799
2020-08	10 000	96 000	10 215	88 583
2020-09	10 000	86 000	10 021	78 562
2020-10	10 000	76 000	9 829	68 733
2020-11	10 000	66 000	9 641	59 092
2020-12	10 000	56 000	9 455	49 638
2021-01	6 000	50 000	5 762	43 876
2021-02	6 000	44 000	5 651	38 225
2021-03	6 000	38 000	5 543	32 682
2021-04	6 000	32 000	5 436	27 247
2021-05	4 000	28 000	3 644	23 602
2021-06	4 000	24 000	3 574	20 028
2021-07	4 000	20 000	3 505	16 523
2021-08	4 000	16 000	3 437	13 087
2021-09	4 000	12 000	3 370	9 717
2021-10	4 000	8 000	3 304	6 413
2021-11	4 000	4 000	3 239	3 174
2021-12	4 000	-	3 174	-

➤ The modelled monthly prepayment rate is equal to 1% for each month

➤ The modelled prepayment rate is multiplied by the outstanding volume of the given homogenic portfolio (166 000 * 1% in January)

The repayment schedule

- **The final product of the model is a modelled, realistic loan repayment schedule for a given, defined earlier loan portfolio**
- The selected model must allow forecasting the monthly prepayment levels for each month until the end of the maturity of the current portfolio
- For example, in case of 35-year mortgage loans, 420 forecasts: 1 for each month
- If for a given portfolio Bank knows (based on real repayment schedules) that customers who take a loan for 10 years pay it back after 8 years on average, Bank should only gather financing for a period of 8 years

Summary & conclusions

Prepayments modeling: summary

- Loan prepayment – very important concept worth understanding from the Bank and customer perspective
- Be creative – **there is many possible modeling approaches that may lead to decent results**
- **In risk modeling the explanation of the following steps is crucial**
- Understand well the business case – what is the final product of the whole modeling proces?



do your thing