

# Lending Club

HarvardX - PH125.9x Data Science Capstone

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*November 07, 2019*

# Contents

<b>Introduction</b>	<b>4</b>
<b>1 Dataset</b>	<b>6</b>
1.1 Preamble . . . . .	6
1.2 General presentation . . . . .	6
1.2.1 Business volume . . . . .	6
1.2.2 Loan lifecycle and status . . . . .	7
1.2.3 Loan application . . . . .	8
1.2.4 Interest rates . . . . .	8
1.2.5 Payments . . . . .	9
1.3 Variables . . . . .	11
1.3.1 General . . . . .	11
1.3.2 Identification . . . . .	11
1.4 Loan decision . . . . .	12
1.5 Payment-related information . . . . .	12
<b>2 Internal Rate of Return and Credit Margins</b>	<b>14</b>
2.1 Important warning . . . . .	14
2.2 Background . . . . .	14
2.3 Internal Rate of Return . . . . .	15
2.4 Dataset . . . . .	16
2.4.1 Calculation . . . . .	16
<b>3 Modelling</b>	<b>17</b>
<b>Appendix</b>	<b>19</b>
3.1 List of assumptions / limitations regarding the dataset . . . . .	19
3.2 Data preparation and formatting . . . . .	19
3.2.1 LendingClub dataset . . . . .	19
3.2.2 Zip codes and FIPS codes . . . . .	26
3.2.3 Market interest rates . . . . .	26
3.2.4 Macro-economical data . . . . .	28
3.3 List of variables . . . . .	30
3.4 Calculations of the internal rate of returns and month-to-default . . . . .	37
3.4.1 R code . . . . .	37
3.4.2 Julia code . . . . .	41
3.5 System version . . . . .	51

# List of Tables

1.1	Number of loans per status . . . . .	7
1.2	Matured loans per status . . . . .	12
3.1	Description of the dataset variables as provided in the dataset downloaded from Kaggle . . . . .	31

# List of Figures

1.1	Interest rates given rating . . . . .	9
1.2	Interest rate per grade over time . . . . .	10
1.3	Historical Swap Rates . . . . .	10
1.4	Credit margins per grade over time . . . . .	11
1.5	Business volume written per month . . . . .	12
1.6	Funding and Write-offs by Sub-grades . . . . .	13
3.1	Scikit Learn algorithm cheat-sheet . . . . .	18

# Introduction

Lending Club (LC) is an American company listed on the New York stock exchange that provides a platform for peer-to-peer lending. Unlike banks, it does not take deposits and invest them. It is purely a matching system. Each loan is split into \$25 that multiple investors can invest in. LC is remunerated by fees received from both sides. LC states that they have intermediated more than \$50bln since they started operations. Further description of the company is easily available online numerous sources.

In order for investors to make the best investment decisions, LC make a historical dataset publicly available to all registered investors. This dataset is the subject of this report. It was downloaded from the Kaggle data science website<sup>1</sup>.

The size of the dataset is rich enough that it could be used to answer many different questions. We decided for a focused approach. Following Chapter 5 of (Peng, 2012), we will first formulate the question we want to answer to guide our analysis.

The business model of LC is to match borrowers and investors. Naturally, more people want to receive money than part with it. An important limiting factor to LC's growth is the ability to attract investors, build a trusting relationship where, as a minimum first step, investors trust LC to provide accurate, transparent and reliable information of the borrowers. For this purpose, LC decided not only to provide extensive information about potential borrowers' profile, but also historical information about past borrowers' performance. This is, as we understand, one of the key purposes of this dataset. We decided to use the dataset for this very purpose. Essentially, the questions are: **given a borrower profile, is his/her rating appropriate in terms of risk of default? And if a default occurs, what is the expected recovery?** The summary question is: **given a borrower profile, is the risk/reward balance appropriate to commit funds?** In answering this question, we understand that LC allows investment of very granular amounts. Therefore, even an individual investor can diversify his/her loan and risk portfolio. It is not necessary to 'gamble' funds on a single borrower. This is exactly what institutional investors achieve through syndication (although on a very different scale, typically \$10-25mln for a medium-size bank).

For this exercise, we made two simplifying (hopefully not simplistic) assumptions:

- In determining the risk/return balance, we have not accounted for LC's cost of intermediation. By ignoring fees paid by both sides, we obviously overestimate the returns to the investors. But in first approximation, **we will assume that the risk/reward balance, from the investors' point of view, across ratings is independent from fees.** This is a simplification. Real-world fees are higher the lower the investment grade and push the investors to receive, and the borrowers to pay, higher interest margin.
- All-in interest rates paid by borrowers are fixed. This is highly desirable for borrowers to be able to manage their cashflow. However, an investor should always consider an investment return as a margin above a risk-free return. Banks would look at LIBOR; bond investors (e.g. life insurers) would look at government bonds. Those risk-free rates can change very quickly, whereas we understand that LC sets those rates on a

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<sup>1</sup><https://www.kaggle.com/wendykan/lending-club-loan-data/data>

less frequent basis. In other word, the risk premium will vary rapidly. **We assume that individual investors are 'in-elastic' to change in implied risk premia.** But we recognise this as a limitation of our work.

This report is organised as follows:

- [XXXX]

# Chapter 1

## Dataset

The data is sourced as a *SQLite* database that was imported as a *data frame* with the *RSQLite* package. The variables were reformatted according to their respective types.

We also sourced US zip and FIPS codes, and macroeconomical data for possible geographical statistics. The source code for the data import and reformatting is given in appendix.

### 1.1 Preamble

The LendingClub dataset, although rich, is difficult to interpret. The only explanation of what the variables mean comes from a spreadsheet attached to the dataset. The explanations are not precise and/or subject to conflicting interpretation. Despite searching the LendingClub website, no further original information was found. We collected a number of reasonable assumptions in Appendix.

The dataset has been used a number of times in the past by various people. One paper ([Kim and Cho, 2019](#)) mentions they used a dataset that included 110 variables, which is less than ours with 145 variables. The dataset has changed over time in ways we do not know.

### 1.2 General presentation

The original dataset is rich: it includes 2260668 loan samples, each containing 145 variables (after the identification variables filled with null values). The loans were issued from 2007-06-01 to 2018-12-01.

#### 1.2.1 Business volume

The dataset represents a total of ca.\$34bln in loan principals, which is a substantial share of the total amount stated to have been intermediated to date by LC (reported to be \$50bln+). About 60% of the portfolio is fully repaid. See Table 1.1.

Figure 1.5 plots the number, volume (cumulative principal amount) and average principal per loan. It shows that the business grew exponentially (in the common sense of the word) from inception until 2016. At this point, according to Wikipedia <sup>1</sup>:

*"Like other peer-to-peer lenders including Prosper, Sofi and Khutzpa.com, LendingClub experienced increasing difficulty attracting investors during early 2016. This led the firm to increase the interest rate it charges borrowers on three*

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<sup>1</sup> source: <https://en.wikipedia.org/wiki/LendingClub> - Retrieval date 15 September 2019

Table 1.1: Number of loans per status

Loan status	Count	Proportion (%)
Charged Off	261655	11.574
Current	919695	40.682
Default	31	0.001
Does not meet the credit policy. Status:Charged Off	761	0.034
Does not meet the credit policy. Status:Fully Paid	1988	0.088
Fully Paid	1041952	46.090
In Grace Period	8952	0.396
Late (16-30 days)	3737	0.165
Late (31-120 days)	21897	0.969

*occasions during the first months of the year. The increase in interest rates and concerns over the impact of the slowing United States economy caused a large drop in LendingClub's share price."*

The number and volume of loans plotted have been aggregated by month. The growth is very smooth in the early years, and suddenly very volatile. As far as the first part of the dataset is concerned, a starting business could expect to be volatile and could witness a yearly cycle (expected from economic consumption figures) superimposed on the growth trend. This is not the case.

An interesting metric is that the average principal of loans has increased (see Figure ??, on a sample of 100,000 loans). Partly, the increase in the early years could be interpreted success in confidence building. This metric plateau-ed in 2016 and decreased afterwards, but to a much lesser extent than the gross volume metrics. However, it is more volatile than the two previous metrics in the early years.

By the end of the dataset, all metrics have essentially recovered to their 2016 level.

### 1.2.2 Loan lifecycle and status

In the dataset, less loans are still outstanding than matured or "charged off" (term that LC use to mean partially or fully written off, i.e. there are no possibilty for LC and/or the investors to receive further payments). The share of outstanding loans is:

<sup>1</sup> ## Share of current loans = 42.214 %

The dataset describes the life cycle of a loan. In the typical (ideal) case, we understand it to be:

Loan is approved → Full amount funded by investors → Loan marked as Current → Fully Paid

In the worst case, it is:

Loan is approved → Full amount funded by investors → Loan marked as Current →

→ Grace period (missed payments under 2 weeks) → Late 15 to 31 days →

→ Late 31 to 120 days → Default → Charged Off

Note that *Default* precedes and is distinct from *Charged Off*<sup>2</sup>. A couple of things could happen to a loan in default:

- LC and the borrower restructure the loan with a new repayment schedule, where the borrower may repay a lesser amount over a longer period; or,
- the claim could be sold to a debt recovery company that would buy the claim from LC/investors. This would be the final payment (if any) received by LC and the investors.

The dataset also describes situations where a borrower negotiated a restructuring of the repayment schedule in case of unexpected hardship (e.g. disaster, sudden unemployment).

Note that this progression of distinguishing default (event in time) and actual financial loss mirrors what banks and rating agencies do. The former is called the *Probability of Default* (PD), the latter *Loss Given Default* (LGD). Ratings change over time (in a process resembling a Markov Chains). LGD show some correlations with ratings. The dataset, although detailed, does not include the full life of each loan to conduct this sort of analysis (change of loan quality over time). This is an important reason why we decided to focus on the loan approval and expected return.

CHANGE: Debt-Settlement companies<sup>3</sup> that explains that debt settlement companies can step in, buy the debt and pay to LC.

CHANGE: What is the difference between a loan that is in “default” and a loan that has been “charged off”?<sup>4</sup>

### 1.2.3 Loan application

Before a loan is approved, the borrower undergoes a review process that assess his/her capacity to repay. This includes:

- employment situation and income, as well whether this income and possibly its source has been independently verified;
- whether the application is made jointly (likely with a partner or a spouse, but there are no details);
- housing situation (owner, owner with current mortgage, rental) and in which county he/she lives (that piece of information is partially anonymised by removing the last 2 digits of the borrower's zipcode);
- the amount sought, its tenor and the purpose of the loan; and,
- what seems to be previous credit history (number of previous delinquencies). The dataset is very confusing in that regard: it is clear that such information relates to before the loan is approved in the case of the joint applicant. In the case of the principal borrower however, the variable descriptions could be read as pre-approval information, or information gathered during the life of the loan. We have assumed that the information related to the principal borrower is also pre-approval. We also used *Sales Supplements* from the LC website<sup>5</sup> that describe some of the information provided to investors. LendingClub also provides a summary description of its approval process in its regulatory filings with the Securities Exchange Commission (California, 2019).

### 1.2.4 Interest rates

Based on this information, the loan is approved or not. Approval includes the final amount (which could be lower than the amount requested), tenor (3 or 5 years) and a rating similar to those given to corporate borrowers. Unlike

<sup>2</sup>See LendingClub FAQ at [and help page](#)

<sup>3</sup><https://help.lendingclub.com/hc/en-us/articles/115011819087-Debt-settlement-companies>

<sup>4</sup><https://help.lendingclub.com/hc/en-us/articles/216127747>

<sup>5</sup>See <https://www.lendingclub.com/legal/prospectus>

Figure 1.1: Interest rates given rating

corporate borrowers however, the rating mechanically determines the rate of interest according to a grid known to the borrower in advance<sup>6</sup>. The rates have changed over time. Those changes were not as frequent as market conditions (e.g. changes in Federal Reserve Bank's rates)<sup>7</sup>.

Figure 1.1<sup>8</sup> shows the predetermined interest rate depending on the initial rating as of July 2019.

At the date of this report, the ratings range from A (the best) down to D, each split in 5 sub-ratings. However, LC previously also intermediated loans rated F or G (until 6 November 2017) and E (until 30 June 2019)<sup>9</sup>. This explains that such ratings are in the dataset. We will assume that the ratings in the dataset are the rating at the time of approval and that, even if loans are re-rated by LC, the dataset does not reflect it.

Figures 1.2 shows the change in interest rate over time for different ratings and separated for each tenor. (Each figure is on a sample of 100,000 loans.) For each rating, we can see several parallel lines which correspond to the 5 sub-rating of each rating. We note that the range of interest rates has substantially widened over time. That is, the risk premium necessary to attract potential investors has had to substantially increase. In the most recent years, the highest rates exceed 30% which is higher than many credit cards. 3-year loans are, unsurprisingly, considered safer (more A-rated, less G-rated). Identical ratings attract identical rates of interest.

By comparison, we plot the 3-year (in red) and 5-year (in blue) bank swap rates in Figure @fig:swap-rates. We see that the swap curve has flattened in recent times (3-year and 5-year rates are almost identical). We also can see that in broad terms the interest rates charged reflect those underlying swap rates. It is therefore most relevant to examine the credit margins added to the swap rates.

Figures 1.4 shows the change in credit margin over time for different ratings and separated for each tenor. (Each figure is on a sample of 100,000 loans.) As above, for each rating, we can see several parallel lines which correspond to the 5 sub-rating of each rating. We note that the range of credit margins has widened over time but less than the interest rates. Identical ratings attract identical credit margins.

[TODO: DTI, amount... by grade]

### 1.2.5 Payments

The loans are approved for only two tenors, 3 and 5 years, with monthly repayments. Installments are calculated easily with the usual formula:

<sup>6</sup><https://www.lendingclub.com/investing/investor-education/interest-rates-and-fees>

<sup>7</sup>Corporate borrowers would negotiate interest margins on a case-by-case basis despite similar risk profiles.

<sup>8</sup>source: <https://www.lendingclub.com/investing/investor-education/interest-rates-and-fees>

<sup>9</sup>See <https://www.lendingclub.com/info/demand-and-credit-profile.action>

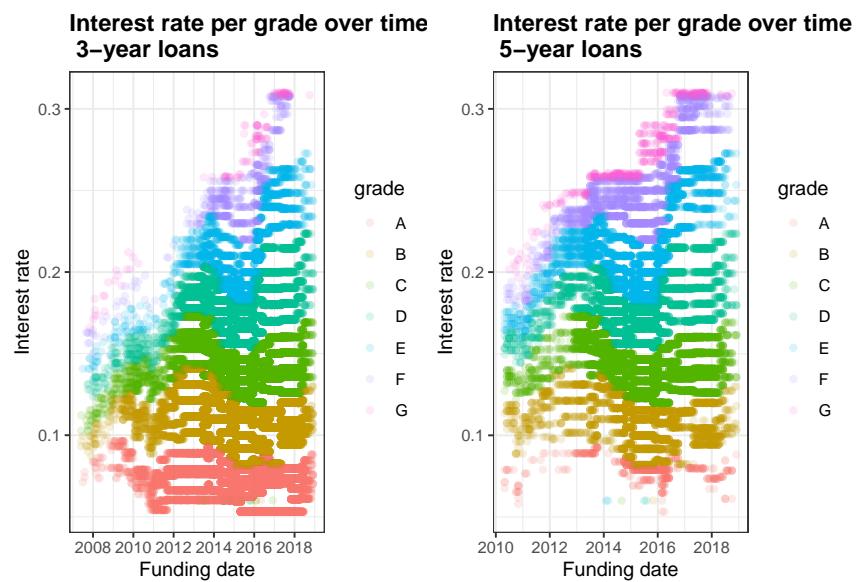


Figure 1.2: Interest rate per grade over time

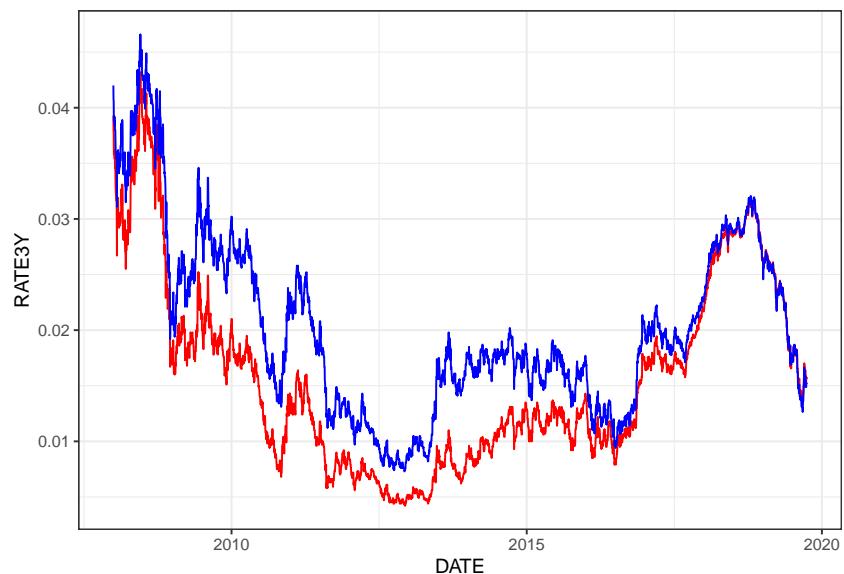


Figure 1.3: Historical Swap Rates

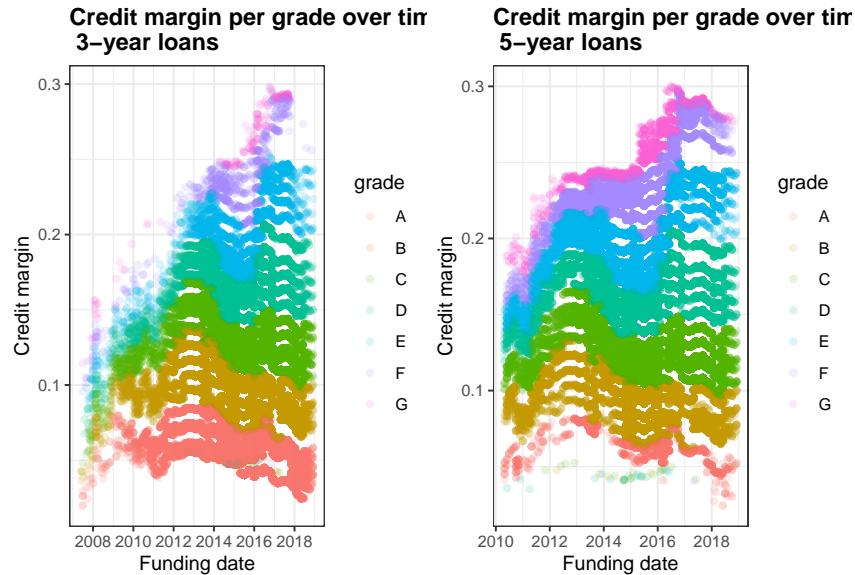


Figure 1.4: Credit margins per grade over time

$$\text{Installment} = \text{Principal} \times \text{rate} \times \frac{1}{1 - \frac{1}{(1+\text{rate})^N}}$$

Where  $\text{Principal}$  is the amount borrowed,  $\text{rate} = \frac{\text{Quoted Interest Rate}}{12}$  is the monthly interest rate, and  $N$  is the number of installments (36 or 60 monthly payments). The following piece of code shows that the average error between this formula and the dataset value is about 2 cents. We therefore precisely understand this variable.

```

1 local({
2   installmentError <- loans %>%
3     mutate(
4       PMT = round(funded_amnt * int_rate / 12 / (1 - 1 / (1 + int_rate / 12) ^
5                     term), 2),
6       PMT_delta = abs(installment - PMT)
7     ) %>%
8     select(PMT_delta)
9
10   round(mean(100 * installmentError$PMT_delta), digits = 2)
11 })

```

## 1.3 Variables

We here present the dataset in a bit more details. The full list of variable is given in appendix (see Table 3.1). This dataset will be reduced as we focused on our core question: *Are LC's loans priced appropriately?*.

### 1.3.1 General

### 1.3.2 Identification

The dataset is anonymised (all identifying ID numbers are deleted) and we therefore removed those columns from the dataset. Since the identification IDs have been removed to anonymise the dataset, we cannot see if a

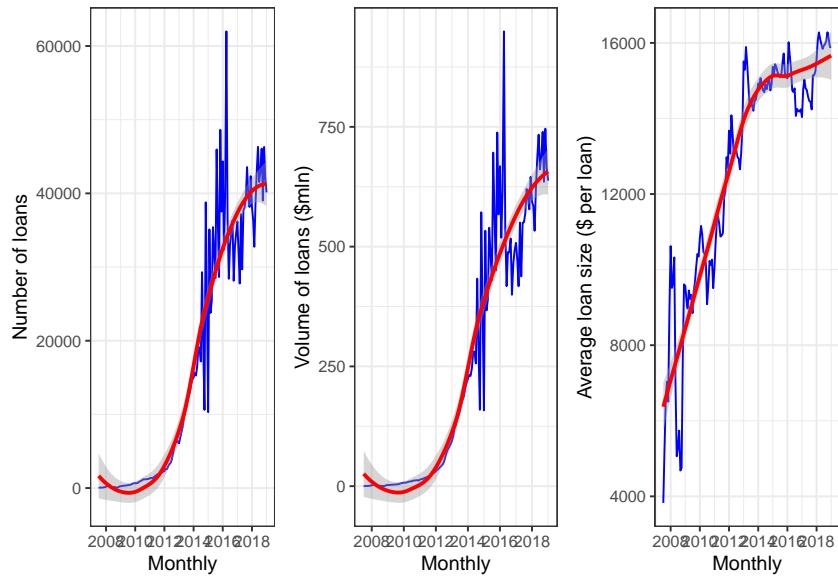


Figure 1.5: Business volume written per month

Table 1.2: Matured loans per status

Loan status	Count	Proportion (%)
Fully Paid	1041952	26048800
Charged Off	261655	6541375
Does not meet the credit policy.	1988	49700
Status:Fully Paid		
Does not meet the credit policy.	761	19025
Status:Charged Off		

borrower borrowed several times.

## 1.4 Loan decision

As indicated in the introduction, our focus is on loans that have gone through their entire life cycle to consider their respective pricing, risk and profitability. To that effect, we will remove all loans which are still current (either performing or not). From here on, everything will be based on this reduced dataset.

In this reduced dataset, we focus on loans that have matured or been terminated. It contains 1306356 samples. Most of the loans (ca.80%) have been repaid in full. See Table 1.2.

When grouped by grade (Figure 1.6), we see a clear correlation between grade and default: the lower the grade the higher the portion defaults (all the way down to about 50%). In addition, most of the business is written in the B- or C-rating range.

## 1.5 Payment-related information

As mentioned previously, the descriptions of the dataset variables is at times incomplete or confusing. For the purpose of determining the cash flow of each individual loans, we have attempted to reconstruct the variables.

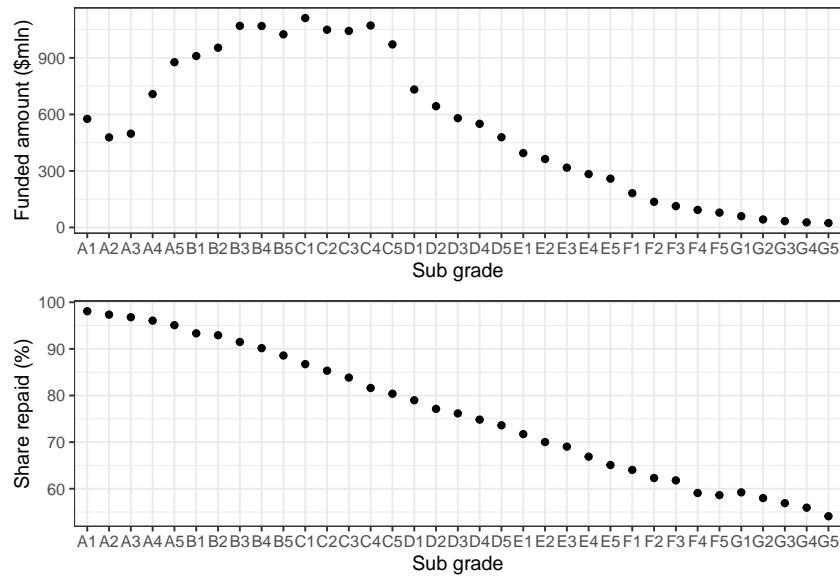


Figure 1.6: Funding and Write-offs by Sub-grades

We have verified that:

- installments are calculated as per the formula shown above, rounded to the next cent.
- $\text{total\_pymnt} = \text{total\_rec\_prncp} + \text{total\_rec\_int} + \text{total\_rec\_late\_fee} + \text{recoveries}$

## Chapter 2

# Internal Rate of Return and Credit Margins

In this section, we describe the responses that we will generate for each loan and that will be used in the modeling section.

As indicated in the introduction, our purpose is to test a model that predicts the financial risk of a loan.

### 2.1 Important warning

The calculations presented here are simplistic. Although they bear some resemblance to what financial institutions do. The literature on credit assessment and pricing is very rich and very complex. Finding the optimal capital allocation to particular risks while at the same time satisfying internal risk policies and regulatory requirements is a problem that financial institutions have still tackle in full. Investing in a loan is not only a matter of assessing the risk of a particular borrower, but also assessing systemic risks (which exist across all borrowers), risks associated with funding the loan (interest, currency and liquidity markets), each requiring a risk assessment and pricing.

In other words, nobody would, let alone should, make any investment decision based on the calculation below.

### 2.2 Background

This subsection can be skipped by anybody with basic financial knowledge.

A bird in hand or two in the bush; a penny today or a pound tomorrow. What is the pricing of delaying obtaining owning something? This is what pricing a loan is about. A lender could keep his/her cash in hand, or lend it and have it in hand later. He/she would accept this in exchange for receiving a bit more: this is the rate of interest.

There are borrowers that one can see as completely safe (risk-free) such as central banks or governments of strong economies. A lender always has the possibility to lend to them instead of a more risky borrower. Therefore, a lender would require a higher interest rate than risk-free. The additional interest that a lender requires is commensurate with the risk of the borrower not repaying (called *credit worthiness*) and is called the *credit margin*.

For each individual borrower, a financial institution (an *FI*) would assess information provided by the borrower and massive amounts of historical data to answer the question: considering historical borrowers with a profile similar to the applicant's, what is the probability of not getting principal and interest back? And, in case the borrower stops paying and using additional courses of action (such as seizing and selling assets), what is the total loss that could be expected on average?

Making that assessment, the *FI* would require an interest rate which would roughly be the sum of:

- the risk-free rate;

- a margin to cover the average loss of similar borrowers (see the important footnote<sup>1</sup>);
- a margin to cover all the operational costs of running their operations; and,
- a margin to remunerate the capital allocated by the FI (banking regulations require all banks to allocate an amount of capital against any risk taken; those are stipulated in a number of complex rules).

Said crudely, this total is the amount for the FI to get out of bed and look at a loan. Although this sounds like an exact science (for some definition of the word), it is not. At the end of the day, the FI will also have to contend with the competition, market liquidity (if there is a lot of money available to be lent, it brings prices down) and, critically, whether would at all be interested in accepting that cost. This already make the dataset not random: many loans do not exist merely because the rate of interest was considered too high (this is not dissimilar to *survival effects* where some data did not survive through the history of a dataset<sup>2</sup>).

## 2.3 Internal Rate of Return

For the purpose of this report, we will simplify things enormously: we will only consider the first two components of the interest rate. The risk-free rate and the credit margin that would cover the cost of default/losses of individual borrowers.

The modeling exercise will focus on trying to approximate *on average* the credit margin given the information provided by the borrower.

With respect to a given loan and its cash flow, two calculations are important here: the Net Present Value (*NPV*) and the Internal Rate of Return (*IRR*). If we remember that an FI is indifferent to holding a principal  $P$  today or receiving it with an annual interest a year later (i.e.  $P \times (1 + r)$  where  $r$  is the annual rate of interest), we can say that any amount  $CF_1$  received in a year is equivalent to  $CF_0 = \frac{CF_1}{1+r}$  today. More generally, a stream of future cash receipts is worth:

$$NPV(r) = \sum_{Year=1}^{Year=n} \frac{CF_i}{(1+r)^i}$$

The amount  $NPV(r)$  is called the *Net Present Value* of the cash flow discounted at the rate  $r$ . Given that the LendingClub repayments are monthly, the formula becomes:

$$NPV(r) = \sum_{Month=1}^{Month=12 \times n} \frac{CF_i}{(1 + \frac{r}{12})^i}$$

If we now have a day 1 cash flow  $CF_0$ , we can calculate:

$$CF_0 - \sum_{Year=1}^{Year=n} \frac{CF_i}{(1+r)^i}$$

However, for any given  $CF_0$ , there is no reason that it would equal the NPV of the future cash flow (i.e no reason why the difference would be equal to zero). But this is an equation depending on  $r$ . If we can find a value of  $r$  that zeroes this formula, it is called the internal rate of return of the cash flow:

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<sup>1</sup>It is important to realise that the average margin only brings the borrower back to having made no money at all on average: the additional income from the credit margin will be spent to cover average losses. In addition, we present the credit margin as income against borrower-specific losses. It does not address a lot of other risks such as correlation risks: a borrower might default because the economy as a whole gets worse, in which case many borrowers will default. This is a cyclical systemic risk similar to the 2007 US real estate crisis.

<sup>2</sup>A well-known example is historical stock prices which disappear when companies are de-listed or go bankrupt.

$$CF_0 - \sum_{Year=1}^{Year=n} \frac{CF_i}{(1 + IRR(CF))^i} = 0$$

or for monthly cash flow:

$$CF_0 - \sum_{Month=1}^{Month=12 \times n} \frac{CF_i}{(1 + \frac{IRR(r)}{12})^i}$$

## 2.4 Dataset

### 2.4.1 Calculation

We used the dataset to calculate the IRR of each loan. We used the following information for the dataset: funded\_amnt (loan amount funded), int\_rate (all-in interest rate), term (tenor of the loan in months), total\_pymnt (total cumulative amount received from the borrower), total\_rec\_prncp (amount repaid allocated to principal repayment), total\_rec\_int (amount repaid allocated to interest payment), recoveries (any amount recovered later from the borrower) and total\_rec\_late\_fee (any late payments fees paid by the borrower).

From that information, we recreated a cash for each loan. The R code is presented in appendix. Unfortunately, this code takes close to a full day to run on the entire dataset of completed loans (i.e. excluding all ongoing loans). This is just impractical for anybody to run to check this report and the resulting dataset is included in the Github repository. To make things practical, the dataset was actually created by Julia code. It is a direct translation of the R code with a similar syntax (therefore very easy to follow). The Julia code runs about 500 times quicker (this is not a typo), or about 3 minutes. We appreciate that this is the departure from the assignment description.

Similarly, we calculate the credit margin required by each loan noting that:

$$\text{Risk-free} + \text{Credit Margin} = IRR(\text{loan})$$

Again, this was coded in Julia (we did not write any R code for this calculation). The code is in appendix, and we believe easy to follow.

## Chapter 3

# Modelling

At the outset, the dataset presents a number of challenges:

- There is a mix of continuous and categorical data.
- The number of observations is very large.
- The possible number of predictors is fairly large.
- As shown in the previous section, credit margins have changed over time. This is clearly related to the wider US economic environment. Financial hardship is a key driver for some of the loans. Availability of disposable income is important to assess the ability to repay. Therefore, the cost of living, which varies from state to state, seems relevant.

Any model will require training through batch methods (e.g. stochastic gradient descent) or online methods. Our intuition is that online methods are not adapted to a skewed dataset: the number of defaults/write-offs is fairly low for high ratings.

The diagram 3.1<sup>1</sup> shows a useful decision tree.

---

<sup>1</sup>Source: [https://scikit-learn.org/stable/tutorial/machine\\_learning\\_map/index.html](https://scikit-learn.org/stable/tutorial/machine_learning_map/index.html)

Figure 3.1: Scikit Learn algorithm cheat-sheet

# Appendix

## 3.1 List of assumptions / limitations regarding the dataset

As mentioned during this report, we had to make numerous assumptions given the lack of clarity of the variable descriptions.

- *Dataset quality:* Aside from cents rounding issues, the dataset does not contain any flagrant errors that we could see (e.g. minor error of amount or rate, zipcode). Quality of the variable description is a different matter altogether.
- *Ratings:* The day-1 rating is between A1 and (and no lower than) G5. No note is rated lower than E5 after 6 November 2017, and lower than D5 after 30 June 2019.
- *Credit history:* Credit history information for the principal borrower relates to pre-approval and not post-funding. This is clear for the joint applicants, but simply an assumption for the principal borrower.
- *Recoveries:* Recoveries (if any) are assumed to be paid 3 months after the last scheduled payment date (variable `last_pymnt_d`)
- *Survival effect:* The dataset does not include applications that were rejected.
- *LIBOR funding rate:* we use the 3-Y and 5\_Y. In reality, we should have used average tenor-weighted swap rates (i.e. ca. 1.5 Y and 2.5 Y). This requires a full swap curve and more calculation than necessary for our purpose. The principles of this report should not be significantly affected by this approximation.

We do hope that LendingClub investors receive information of much better quality!

## 3.2 Data preparation and formatting

We used different sources of information:

- The LendingClub dataset made available on Kaggle;
- US geographical data about zip and FIPS codes;
- Market interest rates from the Saint Louis Federal Reserve Bank; and,
- Macro data from the same source.

We here show the code used to prepare the data. It was automatically formatted by RStudio.

### 3.2.1 LendinClub dataset

```
1 local({  
2     #
```

```

3  # STEP 1: Download the dataset
4  #
5  # Got to https://www.kaggle.com/wendykan/lending-club-loan-data
6  #
7  # Download into the 'datasets' subdirectory
8  # Unzip the file.
9  # WARNING: The unzipping will be about 2.4GB
10 #
11 # Name the sql database "datasets/lending_club.sqlite"
12 #
13 #
14 #
15 # STEP 2: Prepare the database as a tibble
16 #
17 #
18 ##
19 ## WARNING: THIS ASSUMES A 'datasets' DIRECTORY WAS CREATED
20 ##
21 library(RSQLite)
22 db_conn <-
23   dbConnect(RSQLite::SQLite(), "datasets/lending_club.sqlite")
24 dbListTables(db_conn)
25
26 # Returns a 2.96GB data frame
27 lending_club <- dbGetQuery(db_conn, "SELECT * FROM loan")
28 lending_club <- as_tibble(lending_club)
29
30 # Close the database
31 dbDisconnect(db_conn)
32
33 # Compressed to ca.285MB on disk
34 saveRDS(lending_club, "datasets/lending_club.rds")
35
36
37 library(tidyverse)
38 library(lubridate)
39 library(hablar)
40
41 # Before reformat in case the previous step was already done
42 # lending_club <- readRDS("datasets/lending_club.rds")
43 #
44 # str(lending_club)
45 #
46
47 # Leave the original dataset untouched and work with a copy.
48 lc <- lending_club
49
50 lc <- lc %>%
51

```

```

52 # Add loan identification number to track the loans across calculations
53 mutate(loanID = row_number()) %>%
54
55 # Remove useless strings
56 mutate(
57   term      = str_remove(term, " months"),
58   emp_length = str_replace(emp_length, "<1", "0"),
59   emp_length = str_replace(emp_length, "10+", "10"),
60   emp_length = str_remove(emp_length, "years")
61 ) %>%
62
63 # Creates dates out of strings - Parse errors will be raised when no dates.
64 mutate(
65   debt_settlement_flag_date = as_date(dmy(
66     str_c("1-", debt_settlement_flag_date)
67   )),
68   earliest_cr_line         = as_date(dmy(str_c(
69     "1-", earliest_cr_line
70   ))),
71   hardship_start_date      = as_date(dmy(str_c(
72     "1-", hardship_start_date
73   ))),
74   hardship_end_date        = as_date(dmy(str_c(
75     "1-", hardship_end_date
76   ))),
77   issue_d                  = as_date(dmy(str_c("1-", issue_d))),
78   last_credit_pull_d       = as_date(dmy(str_c(
79     "1-", last_credit_pull_d
80   ))),
81   last_pymnt_d             = as_date(dmy(str_c(
82     "1-", last_pymnt_d
83   ))),
84   next_pymnt_d             = as_date(dmy(str_c(
85     "1-", next_pymnt_d
86   ))),
87   payment_plan_start_date  = as_date(dmy(str_c(
88     "1-", payment_plan_start_date
89   ))),
90   sec_app_earliest_cr_line = as_date(dmy(str_c(
91     "1-", sec_app_earliest_cr_line
92   ))),
93   settlement_date           = as_date(dmy(str_c(
94     "1-", settlement_date
95   ))))
96 ) %>%
97
98 # Bulk type conversion with convert from the `hablar` package
99 convert(
100  # Strings

```

```

101     chr(emp_title, title, url, zip_code),
102
103     # Factors
104     fct(
105         addr_state,
106         application_type,
107         debt_settlement_flag,
108         desc,
109         disbursement_method,
110         grade,
111         hardship_flag,
112         hardship_loan_status,
113         hardship_reason,
114         hardship_status,
115         hardship_type,
116         home_ownership,
117         id,
118         initial_list_status,
119         loan_status,
120         member_id,
121         policy_code,
122         purpose,
123         pymnt_plan,
124         settlement_status,
125         sub_grade,
126         verification_status,
127         verification_status_joint
128     ),
129
130     # Integers
131     int(
132         acc_now_delinq,
133         acc_open_past_24mths,
134         chargeoff_within_12_mths,
135         collections_12_mths_ex_med,
136         deferral_term,
137         delinq_2yrs,
138         emp_length,
139         hardship_dpd,
140         hardship_length,
141         inq_fi,
142         inq_last_12m,
143         inq_last_6mths,
144         mo_sin_old_il_acct,
145         mo_sin_old_rev_tl_op,
146         mo_sin_rcnt_rev_tl_op,
147         mo_sin_rcnt_tl,
148         mort_acc,
149         mths_since_last_delinq,

```

```

150     mths_since_last_major_derog,
151     mths_since_last_record,
152     mths_since_rcnt_il,
153     mths_since_recent_bc,
154     mths_since_recent_bc_dlq,
155     mths_since_recent_inq,
156     mths_since_recent_revol_delinq,
157     num_accts_ever_120_pd,
158     num_actv_bc_tl,
159     num_actv_rev_tl,
160     num_bc_sats,
161     num_bc_tl,
162     num_il_tl,
163     num_op_rev_tl,
164     num_rev_accts,
165     num_rev_tl_bal_gt_0,
166     num_sats,
167     num_tl_120dpd_2m,
168     num_tl_30dpd,
169     num_tl_90g_dpd_24m,
170     num_tl_op_past_12m,
171     open_acc,
172     open_acc_6m,
173     open_act_il,
174     open_il_12m,
175     open_il_24m,
176     open_rv_12m,
177     open_rv_24m,
178     sec_app_chargeoff_within_12_mths,
179     sec_app_collections_12_mths_ex_med,
180     sec_app_inq_last_6mths,
181     sec_app_mort_acc,
182     sec_app_mths_since_last_major_derog,
183     sec_app_num_rev_accts,
184     sec_app_open_acc,
185     sec_app_open_act_il,
186     term
187   ),
188
189   # Floating point
190   dbl(
191     all_util,
192     annual_inc,
193     annual_inc_joint,
194     avg_cur_bal,
195     bc_open_to_buy,
196     bc_util,
197     collection_recovery_fee,
198     delinq_amnt,

```

```

199     dti,
200     dti_joint,
201     funded_amnt,
202     funded_amnt_inv,
203     hardship_amount,
204     hardship_last_payment_amount,
205     hardship_payoff_balance_amount,
206     il_util,
207     installment,
208     int_rate,
209     last_pymnt_amnt,
210     loan_amnt,
211     max_bal_bc,
212     orig_projected_additional_accrued_interest,
213     out_prncp,
214     out_prncp_inv,
215     pct_tl_nvr_dlq,
216     percent_bc_gt_75,
217     pub_rec,
218     pub_rec_bankruptcies,
219     recoveries,
220     revol_bal,
221     revol_bal_joint,
222     revol_util,
223     sec_app_revol_util,
224     settlement_amount,
225     settlement_percentage,
226     tax_liens,
227     tot_coll_amt,
228     tot_cur_bal,
229     tot_hi_cred_lim,
230     total_acc,
231     total_bal_ex_mort,
232     total_bal_il,
233     total_bc_limit,
234     total_cu_tl,
235     total_il_high_credit_limit,
236     total_pymnt,
237     total_pymnt_inv,
238     total_rec_int,
239     total_rec_late_fee,
240     total_rec_prncp,
241     total_rev_hi_lim
242   )
243 ) %>%
244
245 # Converts some values to 1/-1 (instead of Boolean)
246 mutate(
247   pymnt_plan = if_else(pymnt_plan == "y", 1, -1),

```

```

248     hardship_flag = if_else(hardship_flag == "Y", 1, -1),
249     debt_settlement_flag = if_else(debt_settlement_flag == "Y", 1, -1)
250 ) %>%
251
252 # Some values are percentages
253 mutate(
254   int_rate = int_rate / 100,
255   dti = dti / 100,
256   dti_joint = dti_joint / 100,
257   revol_util = revol_util / 100,
258   il_util = il_util / 100,
259   all_util = all_util / 100,
260   bc_open_to_buy = bc_util / 100,
261   pct_tl_nvr_dlq = pct_tl_nvr_dlq / 100,
262   percent_bc_gt_75 = percent_bc_gt_75 / 100,
263   sec_app_revol_util = sec_app_revol_util / 100
264 ) %>%
265
266 # Create quasi-centered numerical grades out of grade factors with "A" = 3 down to "G" = -3
267 mutate(grade_num = 4 - as.integer(grade)) %>%
268
269 # Ditto with sub_grades. "A1" = +3.4, "A3" = +3.0, down to "G3" = -3.0, "G5" = -3.4
270 mutate(sub_grade_num = 3.6 - as.integer(sub_grade) / 5) %>%
271
272 # Keep the first 3 digits of the zipcode as numbers
273 mutate(zip_code = as.integer(str_sub(zip_code, 1, 3))) %>%
274
275 # order by date
276 arrange(issue_d) %>%
277
278 # Remove empty columns
279 select(-id, -member_id, -url)
280
281 saveRDS(lc, "datasets/lending_club_reformatted.rds")
282
283
284 # Select loans which have matured or been terminated
285 past_loans <- lc %>%
286   filter(
287     loan_status %in% c(
288       "Charged Off",
289       "Does not meet the credit policy. Status:Charged Off",
290       "Does not meet the credit policy. Status:Fully Paid",
291       "Fully Paid"
292     )
293   )
294
295 saveRDS(past_loans, "datasets/lending_club_reformatted_paid.rds")
296 }```

```

### 3.2.2 Zip codes and FIPS codes

The R package zipcode was installed.

```
1 #  
2 # ZIPCodes dataset.  
3 #  
4  
5 library(zipcode)  
6 data(zipcode)  
7 zips <- zipcode %>%  
8   as_tibble() %>%  
9   mutate(zip = as.integer(str_sub(zip, 1, 3)))  
10  
11 saveRDS(zips, "datasets/zips.rds")
```

A csv file containing zip codes, FIPS codes and population information was downloaded from the *Simple Maps*<sup>2</sup> website.

```
1 local({  
2   kaggleCodes <- read.csv("datasets/csv/ZIP-COUNTY-FIPS_2017-06.csv")  
3  
4   kaggleCodes <-  
5     kaggleCodes %>%  
6     as_tibble() %>%  
7     mutate(zip = floor(ZIP/100),  
8            FIPS = STCOUNTYFP,  
9            COUNTYNAME = str_replace(COUNTYNAME, pattern = "County", replacement = ""),  
10           COUNTYNAME = str_replace(COUNTYNAME, pattern = "Borough", replacement = ""),  
11           COUNTYNAME = str_replace(COUNTYNAME, pattern = "Municipio", replacement = ""),  
12           COUNTYNAME = str_replace(COUNTYNAME, pattern = "Parish", replacement = ""),  
13           COUNTYNAME = str_replace(COUNTYNAME, pattern = "Census Area", replacement = "")) %>%  
14   rename(county = COUNTYNAME) %>%  
15   select(zip, county, FIPS) %>%  
16   arrange(zip)  
17  
18   saveRDS(zipfips, "datasets/kaggleCodes.rds")  
19 })
```

### 3.2.3 Market interest rates

Market interest rates (3-year and 5-year swap rates) were download from the Saint Louis Federal Reserve Bank. Datasets are split between before and after the LIBOR fixing scandal. The datasets are merged with distinct dates.

Download sources are:

- Pre-LIBOR 3-y swap <https://fred.stlouisfed.org/series/DSWP3>
- Post-LIBOR 3-y swap <https://fred.stlouisfed.org/series/ICERATES1100USD3Y>
- Pre-LIBOR 5-y swap <https://fred.stlouisfed.org/series/MSWP5>

---

<sup>2</sup><https://simplemaps.com/data/us-zips>

- Post-LIBOR 5-y swap <https://fred.stlouisfed.org/series/ICERATES1100USD5Y>

```

1 local({
2   LIB0R3Y <- read.csv("datasets/csv/DSWP3.csv") %>%
3     as_tibble() %>%
4     filter(DSWP3 != ".") %>%
5     mutate(DATE = as_date(DATE),
6           RATE3Y = as.numeric(as.character(DSWP3)) / 100) %>%
7     select(DATE, RATE3Y)
8
9   ICE3Y <- read.csv("datasets/csv/ICERATES1100USD3Y.csv") %>%
10    as_tibble() %>%
11    filter(ICERATES1100USD3Y != ".") %>%
12    mutate(DATE = as_date(DATE),
13           RATE3Y = as.numeric(as.character(ICERATES1100USD3Y)) / 100) %>%
14    select(DATE, RATE3Y)
15
16
17   LIB0R5Y <- read.csv("datasets/csv/DSWP5.csv") %>%
18     as_tibble() %>%
19     filter(DSWP5 != ".") %>%
20     mutate(DATE = as_date(DATE),
21           RATE5Y = as.numeric(as.character(DSWP5)) / 100) %>%
22     select(DATE, RATE5Y)
23
24   ICE5Y <- read.csv("datasets/csv/ICERATES1100USD5Y.csv") %>%
25     as_tibble() %>%
26     filter(ICERATES1100USD5Y != ".") %>%
27     mutate(DATE = as_date(DATE),
28           RATE5Y = as.numeric(as.character(ICERATES1100USD5Y)) / 100) %>%
29     select(DATE, RATE5Y)
30
31   RATES3Y <- LIB0R3Y %>% rbind(ICE3Y) %>%
32     arrange(DATE) %>% distinct(DATE, .keep_all = TRUE)
33
34   RATES5Y <- LIB0R5Y %>% rbind(ICE5Y) %>%
35     arrange(DATE) %>% distinct(DATE, .keep_all = TRUE)
36
37   saveRDS(RATES3Y, "datasets/rates3Y.rds")
38   saveRDS(RATES5Y, "datasets/rates5Y.rds")
39
40
41 # Note there are 7212 days from 1 Jan 2000 to 30 Sep 2019
42 #
43 # (ymd("2000-01-01") %--% ymd("2019-09-30")) %/%
44 # days(1)
44 RATES <- tibble(n = seq(0, 7212)) %>%
45
46   # Create a column with all dates
47   mutate(DATE = ymd("2000-01-01") + days(n)) %>%
48   select(-n) %>%

```

```

49
50 # Add all daily 3- then 5-year rates and fill missing down
51 left_join(RATES3Y) %>%
52   fill(RATE3Y, .direction = "down") %>%
53
54 left_join(RATES5Y) %>%
55   fill(RATE5Y, .direction = "down")
56
57 saveRDS(RATES, "datasets/rates.rds")
58 })

```

### 3.2.4 Macro-economical data

Macro-economical datasets were sourced from the same website as Microsoft Excel files. They were converted as-is to tab-separated csv files with LibreOffice.

- Median income per household: <https://geofred.stlouisfed.org/map/?th=pubugn&cc=5&rc=false&im=fractile&sb&lng=-112.41&lat=44.31&zm=4&sl&sv&am=Average&at=Not%20Seasonally%20Adjusted,%20Annual,%20Dollars&sti=2022&fq=Annual&rt=county&un=lin&dt=2017-01-01>
- Per capita personal income: <https://geofred.stlouisfed.org/map/?th=pubugn&cc=5&rc=false&im=fractile&sb&lng=-112.41&lat=44.31&zm=4&sl&sv&am=Average&at=Not%20Seasonally%20Adjusted,%20Annual,%20Dollars&sti=882&fq=Annual&rt=county&un=lin&dt=2017-01-01>
- Unemployment: <https://geofred.stlouisfed.org/map/?th=rdpu&cc=5&rc=false&im=fractile&sb&lng=-90&lat=40&zm=4&sl&sv&am=Average&at=Not%20Seasonally%20Adjusted,%20Monthly,%20Percent&sti=1224&fq=Monthly&rt=county&un=lin&dt=2019-08-01>

```

1 local{
2   #####
3   ##
4   ## Median income per household by FIPS from 2002 to 2017
5   ##
6   # Prepare median income
7   medianIncome <-
8     # Load the dataset after dropping the first line
9   read.csv(
10    "datasets/csv/GeoFRED_Estimate_of_Median_Household_Income_by_County_Dollars.csv",
11    sep = "\t",
12    skip = 1,
13    stringsAsFactors = FALSE
14  ) %>%
15
16  # Drops columns containing a unique identifier and the FIPS name
17  select(-"Series.ID", -"Region.Name") %>%
18
19  # Rename the relevant column to 'FIPS'
20  rename(FIPS = "Region.Code") %>%
21
22  # Order by FIPS
23  arrange(FIPS) %>%

```

```

24
25 # Convert to a 'long' table, i.e. one column for FIPS, one for date, one for income
26 pivot_longer(cols = starts_with("X"),
27               names_to = "Date",
28               values_to = "medianIncome") %>%
29
30 # Create actual dates
31 mutate(Date = str_replace(Date, "[X]", ""),
32        Date = ymd(str_c(Date, "-12-31")))
33
34 saveRDS(medianIncome, "datasets/medianincome.rds")
35
36
37 #####
38 ## Per capita income by FIPS from 2002 to 2017
39 ##
40 personalIncome <-
41   # Load the dataset after dropping the first line
42   read.csv(
43     "datasets/csv/GeoFRED_Per_Capita_Personal_Income_by_County_Dollars.csv",
44     sep = "\t",
45     skip = 1,
46     stringsAsFactors = FALSE
47   ) %>%
48
49 # Drops columnsn containing a unique identifier and the FIPS name
50 select(-"Series.ID", -"Region.Name") %>%
51
52 # Rename the relevant column to 'FIPS'
53 rename(FIPS = "Region.Code") %>%
54
55 # Order by FIPS
56 arrange(FIPS) %>%
57
58 # Convert to a 'long' table, i.e. one column for FIPS, one for date, one for income
59 pivot_longer(cols = starts_with("X"),
60               names_to = "Date",
61               values_to = "personalIncome") %>%
62
63 # Create actual dates
64 mutate(Date = str_replace(Date, "[X]", ""),
65        Date = ymd(str_c(Date, "-12-31")))
66
67 saveRDS(personalIncome, "datasets/personalincome.rds")
68
69 #####
70
71
72 #####

```

```

73  ##
74  ## Unemployment rate monthly by FIPS from January 2000 to August 2019
75  ##
76  unemploymentRate <-
77  # Load the dataset after dropping the first line
78  read.csv(
79      "datasets/csv/GeoFRED_Unemployment_Rate_by_County_Percent.csv",
80      sep = "\t",
81      skip = 1,
82      stringsAsFactors = FALSE
83  ) %>%
84
85  # Drops columns containing a unique identifier and the FIPS name
86  select(-Series.ID, -Region.Name) %>%
87
88  # Rename the relevant column to 'FIPS'
89  rename(FIPS = "Region.Code") %>%
90
91  # Order by FIPS
92  arrange(FIPS) %>%
93
94  mutate_all(as.double) %>%
95
96  # Convert to a 'long' table, i.e. one column for FIPS, one for date, one for income
97  pivot_longer(cols = starts_with("X"),
98      names_to = "Date",
99      values_to = "unemploymentRate",
100     values_ptypes = c("unemploymentRate", numeric)) %>%
101
102  # Converts the content of the Year column to an actual date
103  mutate(
104      Date = str_replace(Date, "[X]", ""),
105      Date = str_replace(Date, "[.]", "-"),
106      Date = ymd(str_c(Date, "-1"))
107  )
108
109  saveRDS(unemploymentRate, "datasets/unemployment.rds")
110 }

```

### 3.3 List of variables

This table presents the list of variables provided in the original dataset. The descriptions come from a spreadsheet attached with the dataset and, unfortunately, are not extremely precise and subject to interpretation. We added comments and/or particular interpretations in **CAPITAL LETTERS**.

Table 3.1: Description of the dataset variables as provided in the dataset downloaded from Kaggle

Variable Name	Description
loanID	NOTE THIS IS NOT AN ORIGINAL VARIABLE. IT WAS ADDED FOR THE PURPOSE OF TRACKING LOANS INDIVIDUALLY AS AND WHEN NEEDED.
loan_amnt	The listed amount of the loan applied for by the borrower. If at some point in time, the credit department reduces the loan amount, then it will be reflected in this value.
funded_amnt	The total amount committed to that loan at that point in time.
funded_amnt_inv	The total amount committed by investors for that loan at that point in time.
term	The number of payments on the loan. Values are in months and can be either 36 or 60.
int_rate	Interest Rate on the loan
installment	The monthly payment owed by the borrower if the loan originates.
grade	LC assigned loan grade
sub_grade	LC assigned loan subgrade
emp_title	The job title supplied by the Borrower when applying for the loan.
emp_length	Employment length in years. Possible values are between 0 and 10 where 0 means less than one year and 10 means ten or more years.
home_ownership	The home ownership status provided by the borrower during registration or obtained from the credit report. Our values are: RENT, OWN, MORTGAGE, OTHER, NONE
annual_inc	The self-reported annual income provided by the borrower during registration. NOT USED AS A VARIABLE SINCE JOINT INCOME ALREADY INCLUDES IT.
verification_status	Indicates if income was verified by LC, not verified, or if the income source was verified
issue_d	The month which the loan was funded
loan_status	Current status of the loan
pymnt_plan	Indicates if a payment plan has been put in place for the loan
url	URL for the LC page with listing data.
desc	Loan description provided by the borrower
purpose	A category provided by the borrower for the loan request.
title	The loan title provided by the borrower

Table 3.1: Description of the dataset variables as provided in the dataset downloaded from Kaggle (*continued*)

Variable Name	Description
zip_code	The first 3 numbers of the zip code provided by the borrower in the loan application.
addr_state	The state provided by the borrower in the loan application
dti	A ratio calculated using the borrower s total monthly debt payments on the total debt obligations, excluding mortgage and the requested LC loan, divided by the borrower s self-reported monthly income. NOT USED AS A VARIABLE. ONLY USE JOINT DTI.
delinq_2yrs	The number of 30+ days past-due incidences of delinquency in the borrower s credit file for the past 2 years
earliest_cr_line	The month the borrower s earliest reported credit line was opened
inq_last_6mths	The number of inquiries in past 6 months (excluding auto and mortgage inquiries)
mths_since_last_delinq	The number of months since the borrower s last delinquency.
mths_since_last_record	The number of months since the last public record.
open_acc	The number of open credit lines in the borrower s credit file.
pub_rec	Number of derogatory public records
revol_bal	Total credit revolving balance
revol_util	Revolving line utilization rate, or the amount of credit the borrower is using relative to all available revolving credit.
total_acc	The total number of credit lines currently in the borrower s credit file
initial_list_status	The initial listing status of the loan. Possible values are – W, F
out_prncp	Remaining outstanding principal for total amount funded. NOTE ONCE A LOAN IS REPAYED OR CHARGED OFF, THIS AMOUNT BECOMES 0.
out_prncp_inv	Remaining outstanding principal for portion of total amount funded by investors. NOTE ONCE A LOAN IS REPAYED OR CHARGED OFF, THIS AMOUNT BECOMES 0.
total_pymnt	Payments received to date for total amount funded
total_pymnt_inv	Payments received to date for portion of total amount funded by investors

Table 3.1: Description of the dataset variables as provided in the dataset downloaded from Kaggle (*continued*)

Variable Name	Description
total_rec_prncp	Principal received to date. NOTE THIS AMOUNT WILL SHOW WHETHER A BORROWER DID NOT REPAY IN FULL
total_rec_int	Interest received to date
total_rec_late_fee	Late fees received to date
recoveries	Post charge off gross recovery. NOTE IF A LOAN IS REPAYED, THIS AMOUNT IS 0.
collection_recovery_fee	Post charge off collection fee
last_pymnt_d	Last month payment was received
last_pymnt_amnt	Last total payment amount received
next_pymnt_d	Next scheduled payment date
last_credit_pull_d	The most recent month LC pulled credit for this loan
collections_12_mths_ex_med	Number of collections in 12 months excluding medical collections
mths_since_last_major_derog	Months since most recent 90-day or worse rating
policy_code	Publicly available policy_code=1 / New products not publicly available policy_code=2
application_type	Indicates whether the loan is an individual application or a joint application with two coborrowers
annual_inc_joint	The combined self-reported annual income provided by the coborrowers during registration
dti_joint	A ratio calculated using the coborrowers total monthly payments on the total debt obligations, excluding mortgages and the requested LC loan, divided by the coborrowers combined self-reported monthly income
verification_status_joint	Indicates if income was verified by LC, not verified, or if the income source was verified
acc_now_delinq	The number of accounts on which the borrower is now delinquent.
tot_coll_amt	Total collection amounts ever owed
tot_cur_bal	Total current balance of all accounts
open_acc_6m	Number of open trades in last 6 months
open_act_il	Number of currently active installment trades
open_il_12m	Number of installment accounts opened in past 12 months
open_il_24m	Number of installment accounts opened in past 24 months
mths_since_rcnt_il	Months since most recent instalment accounts opened
total_bal_il	Total current balance of all installment accounts

Table 3.1: Description of the dataset variables as provided in the dataset downloaded from Kaggle (*continued*)

Variable Name	Description
il_util	Ratio of total current balance to high credit/credit limit on all install acct
open_rv_12m	Number of revolving trades opened in past 12 months
open_rv_24m	Number of revolving trades opened in past 24 months
max_bal_bc	Maximum current balance owed on all revolving accounts
all_util	Balance to credit limit on all trades
total_rev_hi_lim	Total revolving high credit/credit limit
inq_fi	Number of personal finance inquiries
total_cu_tl	Number of finance trades
inq_last_12m	Number of credit inquiries in past 12 months
acc_open_past_24mths	Number of trades opened in past 24 months.
avg_cur_bal	Average current balance of all accounts
bc_open_to_buy	Total open to buy on revolving bankcards.
bc_util	Ratio of total current balance to high credit/credit limit for all bankcard accounts.
chargeoff_within_12_mths	Number of charge-offs within 12 months
delinq_amnt	The past-due amount owed for the accounts on which the borrower is now delinquent.
mo_sin_old_il_acct	Months since oldest bank instalment account opened
mo_sin_old_rev_tl_op	Months since oldest revolving account opened
mo_sin_rcnt_rev_tl_op	Months since most recent revolving account opened
mo_sin_rcnt_tl	Months since most recent account opened
mort_acc	Number of mortgage accounts.
mths_since_recent_bc	Months since most recent bankcard account opened.
mths_since_recent_bc_dlq	Months since most recent bankcard delinquency
mths_since_recent_inq	Months since most recent inquiry.
mths_since_recent_revol_delinq	Months since most recent revolving delinquency.
num_accts_ever_120_pd	Number of accounts ever 120 or more days past due
num_actv_bc_tl	Number of currently active bankcard accounts
num_actv_rev_tl	Number of currently active revolving trades
num_bc_sats	Number of satisfactory bankcard accounts
num_bc_tl	Number of bankcard accounts
num_il_tl	Number of installment accounts
num_op_rev_tl	Number of open revolving accounts
num_rev_accts	Number of revolving accounts
num_rev_tl_bal_gt_0	Number of revolving trades with balance >0

Table 3.1: Description of the dataset variables as provided in the dataset downloaded from Kaggle (*continued*)

Variable Name	Description
num_sats	Number of satisfactory accounts
num_tl_120dpd_2m	Number of accounts currently 120 days past due (updated in past 2 months)
num_tl_30dpd	Number of accounts currently 30 days past due (updated in past 2 months)
num_tl_90g_dpd_24m	Number of accounts 90 or more days past due in last 24 months
num_tl_op_past_12m	Number of accounts opened in past 12 months
pct_tl_nvr_dlq	Percent of trades never delinquent
percent_bc_gt_75	Percentage of all bankcard accounts > 75% of limit.
pub_rec_bankruptcies	Number of public record bankruptcies
tax_liens	Number of tax liens
tot_hi_cred_lim	Total high credit/credit limit
total_bal_ex_mort	Total credit balance excluding mortgage
total_bc_limit	Total bankcard high credit/credit limit
total_il_high_credit_limit	Total installment high credit/credit limit
revol_bal_joint	Total credit revolving balance
sec_app_earliest_cr_line	Earliest credit line at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_inq_last_6mths	Credit inquiries in the last 6 months at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_mort_acc	Number of mortgage accounts at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_open_acc	Number of open trades at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_revol_util	Ratio of total current balance to high credit/credit limit for all revolving accounts. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_open_act_il	Number of currently active installment trades at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.

Table 3.1: Description of the dataset variables as provided in the dataset downloaded from Kaggle (*continued*)

Variable Name	Description
sec_app_num_rev_accts	Number of revolving accounts at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_chargeoff_within_12_mths	Number of charge-offs within last 12 months at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_collections_12_mths_ex_med	Number of collections within last 12 months excluding medical collections at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
sec_app_mths_since_last_major_derog	Months since most recent 90-day or worse rating at time of application for the secondary applicant. VARIABLE NOT USED. WE RELY ON THE MAIN BORROWER IN THE FIRST INSTANCE.
hardship_flag	Flags whether or not the borrower is on a hardship plan
hardship_type	Describes the hardship plan offering
hardship_reason	Describes the reason the hardship plan was offered
hardship_status	Describes if the hardship plan is active, pending, cancelled, completed, or broken
deferral_term	Amount of months that the borrower is expected to pay less than the contractual monthly payment amount due to a hardship plan
hardship_amount	The interest payment that the borrower has committed to make each month while they are on a hardship plan
hardship_start_date	The start date of the hardship plan period
hardship_end_date	The end date of the hardship plan period
payment_plan_start_date	The day the first hardship plan payment is due. For example, if a borrower has a hardship plan period of 3 months, the start date is the start of the three-month period in which the borrower is allowed to make interest-only payments.
hardship_length	The number of months the borrower will make smaller payments than normally obligated due to a hardship plan
hardship_dpd	Account days past due as of the hardship plan start date
hardship_loan_status	Loan Status as of the hardship plan start date

Table 3.1: Description of the dataset variables as provided in the dataset downloaded from Kaggle (continued)

Variable Name	Description
orig_projected_additional_accrued_interest	The original projected additional interest amount that will accrue for the given hardship payment plan as of the Hardship Start Date. This field will be null if the borrower has broken their hardship payment plan.
hardship_payoff_balance_amount	The payoff balance amount as of the hardship plan start date
hardship_last_payment_amount	The last payment amount as of the hardship plan start date
disbursement_method	The method by which the borrower receives their loan. Possible values are: CASH, DIRECT_PAY
debt_settlement_flag	Flags whether or not the borrower, who has charged-off, is working with a debt-settlement company.
debt_settlement_flag_date	The most recent date that the Debt_Settlement_Flag has been set
settlement_status	The status of the borrower's settlement plan. Possible values are: COMPLETE, ACTIVE, BROKEN, CANCELLED, DENIED, DRAFT
settlement_date	The date that the borrower agrees to the settlement plan
settlement_amount	The loan amount that the borrower has agreed to settle for
settlement_percentage	The settlement amount as a percentage of the payoff balance amount on the loan
settlement_term	The number of months that the borrower will be on the settlement plan

## 3.4 Calculations of the internal rate of returns and month-to-default

The following shows two versions of the same code. The R version is provided because of the description of the assignment. However, the R version takes just under a full day to run. A Julia version, which is a direct translation of the R code, runs in about 150s (ca. 500x faster).

### 3.4.1 R code

```

1 #####
2 #
3 # Given some numerical parameters describing a loan in the dataset, returns its Internal Rate
4 # of Return.
5 #
6 # In the first instance, the function creates a schedule of payments.
7 # In many cases, the schedule will be extremely simple: a series of 36 or 60 equal instalments.

```

```

8  #
9  # But in some cases, a loan repayment are accelerated. Therefore the total amount of interest will
10 # be lower than expected (but this is good for the investor because highe interest rate over
11 # shorter tenor.).#
12 #
13 # In other cases, the borrower defaults. Overall payments are less than expected.
14 #
15 # Based on the limited information of the dataset, the function makes educated guesses on the exact schedule.
16 #
17 # WARNING: THIS IS NOT OPTIMISED. RUNNING THIS FOR ALL LOANS (1.3 MLN OF THEM) TAKES CA.20 HOURS !!!!
18 #
19 calculateIRR <- function(loanNumber = 1,
20                         loan,
21                         intRate,
22                         term = 36,
23                         totalPaid,
24                         totalPrincipalPaid,
25                         totalInterestPaid,
26                         recoveries = 0,
27                         lateFees = 0,
28                         showSchedule = FALSE) {
29   require(tidyverse)
30
31   # number of monthly payments.
32   # It exceeds 60 months in case recoveries on a 60-month loan takes the schedule after 60 months.
33   nMonths <- 90
34
35   # Months after which a loan defaults (normal tenor if no default or early prepayment)
36   monthDefault = term
37
38   # Note: *100 /100 to calculate in cent because ceiling cannot specify significant digits.
39   installment <-
40     ceiling(100 * loan * intRate / 12 / (1 - 1 / (1 + intRate / 12) ^ term)) / 100
41
42   # We create a schedule
43   schedule <- tibble(
44     month = 0:nMonths,
45     monthlyPayment = 0.0,
46     totalPandI = 0.0,
47     totalI = 0.0,
48     totalP = 0.0
49   )
50
51   for (i in 2:(nMonths + 2)) {
52     # Get situation at the end of previous month
53     previousTotalPandI <- as.numeric(schedule[i - 1, "totalPandI"])
54     previousTotalP    <- as.numeric(schedule[i - 1, "totalP"])
55     previousTotalI    <- as.numeric(schedule[i - 1, "totalI"])
56

```

```

57 # This is the beginning of a new month. First and foremost, the borrower is expected to pay the
58 # accrued interest on amount of principal outstanding.
59 # ceiling doesn't seem accept to accept significative digits.
60 accruedInterest <-
61   ceiling(100 * (loan - previousTotalP) * intRate / 12) / 100
62
63 # If that amount takes the schedule above the total amount of interest shown in the data set,
64 # we should stop the schedule at this point
65 if (previousTotalI + accruedInterest > totalInterestPaid) {
66   # We stop the normal schedule at this date.
67   # Interest is paid (although less than scheduled)
68   schedule[i, "monthlyPayment"] <-
69     totalInterestPaid - previousTotalI
70
71   # As well as whatever principal is left as per the dataset
72   schedule[i, "monthlyPayment"] <-
73     schedule[i, "monthlyPayment"] + totalPrincipalPaid - previousTotalP
74
75   # Then 3-month after the last payment date, recoveries and late fees are paid
76   schedule[i + 3, "monthlyPayment"] <-
77     schedule[i + 3, "monthlyPayment"] + recoveries + lateFees
78
79   # Not really useful, but for completeness
80   schedule[i, "totalPandI"] <- totalPaid
81   schedule[i, "totalI"]      <- totalInterestPaid
82   schedule[i, "totalP"]      <- totalPrincipalPaid
83
84   # If total principal paid is less than borrower, then it is a default, and the monthDefault
85   # is adjusted.
86   if (totalPrincipalPaid < loan) {
87     monthDefault = i
88   }
89
90   # No more payments to add to the schedule
91   break()
92
93 } else {
94   # Deal with normal schedule
95   schedule[i, "monthlyPayment"] <- installment
96   schedule[i, "totalPandI"] <-
97     schedule[i - 1, "totalPandI"] + installment
98   schedule[i, "totalI"]      <-
99     schedule[i - 1, "totalI"]  + accruedInterest
100  schedule[i, "totalP"]      <-
101    schedule[i - 1, "totalP"] + installment - accruedInterest
102 }
103 }
104
105 # At this point schedule[, "monthlyPayment"] contains the schedule of all payments, but needs to

```

```

106  # include the initial loan.
107  schedule[1, "monthlyPayment"] <- -loan
108
109  if (showSchedule) {
110    schedule %>% view()
111  }
112
113  NPV <- function(interest, cashFlow) {
114    t = 0:(length(cashFlow) - 1)
115    sum(cashFlow / (1 + interest)^t)
116  }
117
118  IRR <- function(CF) {
119    res <- NA
120    try({
121      res <- uniroot(NPV, c(-0.9, 1), cashFlow = CF)$root
122    },
123      silent = TRUE)
124    return(res)
125  }
126
127  return(tibble(
128    loanID = loanNumber,
129    IRR = round(as.numeric(IRR(
130      schedule$monthlyPayment
131    ) * 12), digits = 4),
132    monthDefault = monthDefault
133  ))
134}
135
136 loanNumberIRR <- function(loanNumber) {
137   require(tidyverse)
138
139   l <- loans %>% filter(loanID == loanNumber)
140   calculateIRR(
141     loanNumber = l$loanID,
142     loan = l$funded_amnt, intRate = l$int_rate, term = l$term,
143     totalPaid = l$total_pymnt, totalPrincipalPaid = l$total_rec_prncp, totalInterestPaid = l$total_rec_int,
144     recoveries = l$recoveries, lateFees = l$total_rec_late_fee,
145     showSchedule = TRUE
146   )
147 }
1
2  #
3  # Calculate all the IRRs and month of default for all the loans.
4  # WARNING: This takes around a full day to run!!!
5  #
6  # The actual data was generated by the Julia version, with cross-checks.
7  # Julia version takes about 150 sec on the same unoptimised code.

```

```

7  #
8  local{
9    loansIRR <-
10   loans %>%
11   rowwise() %>%
12   do(calculateIRR(loanNumber = .loanID,
13        loan = .funded_amnt, intRate = .int_rate, term = .term,
14        totalPaid = .total_pymnt, totalPrincipalPaid = .total_rec_prncp,
15        totalInterestPaid = .total_rec_int,
16        recoveries = .recoveries, lateFees = .total_rec_late_fee))
17
18   saveRDS(loansIRR, "datasets/lending_club_IRRs.rds")
19
20 }

```

### 3.4.2 Julia code

#### 3.4.2.1 Translation of IRR

```

1 #####
2 ##
3 ## Prepare datasets
4 ##
5
6 ## Previously saved from R with:
7 ##     lending_club <- readRDS("lending_club.rds"); write.csv(lending_club, "lending_club.rds")
8 ##
9 ## WARNING: 1.7GB on disk
10 ##
11 using CSV
12 lendingClub = CSV.read("datasets/lending_club.csv"; delim = ",")
13
14
15 #####
16 ##
17 ##
18 ## IRR calculations
19 ##
20 ## Given some numerical parameters describing a loan in the dataset, returns its Internal Rate
21 ## of Return.
22 ##
23 ## In the first instance, the function creates a schedule of payments.
24 ## In many cases, the schedule will be extremely simple: a series of 36 or 60 equal instalments.
25 ##
26 ## But in some cases, a loan repayment are accelerated. Therefore the total amount of interest will
27 ## be lower than expected (but this is good for the investor because highe interest rate over
28 ## shorter tenor.).
29 ##
30 ## In other cases, the borrower defaults. Overall payments are less than expected.

```

```

31  ##
32  ## Based on the limited information of the dataset, the function makes educated guesses on the exact
33  ## schedule.
34  ##
35  using DataFrames, Roots
36
37  function calculateIRR(; loanNumber = 1, loan = 0.0, intRate = 0.0, term = 36,
38      totalPaid = 0.0, totalPrincipalPaid = 0.0, totalInterestPaid = 0.0,
39      recoveries = 0.0, lateFees = 0.0,
40      showSchedule = false)
41
42  # number of monthly payments.
43  # It exceeds 60 months in case recoveries on a 60-month loan takes the schedule after 60 months.
44  nMonths = 90
45
46  # Months after which a loan defaults (normal tenor if no default or early prepayment)
47  monthDefault = term
48
49  # Note: *100 /100 to calculate in cent because ceiling cannot specify significant digits.
50  installment = ceil(loan * intRate / 12 / (1 - 1 / (1 + intRate / 12) ^ term), digits = 2)
51
52  # We create a schedule
53  schedule = DataFrame(month = 0:nMonths, monthlyPayment = 0.0,
54                      totalPandI = 0.0, totalI = 0.0, totalP = 0.0)
55
56  for i in 2:(nMonths + 1)
57  # Get situation at the end of previous month
58  previousTotalPandI = schedule[i - 1, :totalPandI]
59  previousTotalP     = schedule[i - 1, :totalP]
60  previousTotalI    = schedule[i - 1, :totalI]
61
62  # This is the beginning of a new month. First and foremost, the borrower is expected to pay the
63  # accrued interest on amount of principal outstanding.
64  # The installment is expected to cover that amount of interest and the rest goes to
65  # reducing the principal due outstanding.
66  accruedInterest = ceil((loan - previousTotalP) * intRate / 12; digits = 2)
67  decreasePrincipal = installment - accruedInterest
68
69  # If that amount takes the schedule above the total amount of interest shown in the data set,
70  # we should stop the schedule at this point
71  # This is a shortcut since we could have a payment higher than the interest due, but not enough
72  # to cover the expected principal repayment. However, it works well in practice.
73  if previousTotalI + accruedInterest > totalInterestPaid
74
75  # We stop the normal schedule at this date.
76  # Interest is paid (although less than scheduled)
77  schedule[i, :monthlyPayment] = totalInterestPaid - previousTotalI
78
79  # As well as whatever principal is left as per the dataset

```

```

80     schedule[i, :monthlyPayment] = schedule[i, :monthlyPayment] + totalPrincipalPaid - previousTotalP
81
82     # Then 3-month after the last payment date, recoveries and late fees are paid
83     schedule[i + 3, :monthlyPayment] = schedule[i + 3, :monthlyPayment] + recoveries + lateFees
84
85     # Not really useful, but for completeness
86     schedule[i, :totalPandI] = totalPaid
87     schedule[i, :totalI]      = totalInterestPaid
88     schedule[i, :totalP]      = totalPrincipalPaid
89
90     # If total principal paid is less than borrower, then it is a default, and the monthDefault
91     # is adjusted.
92     if (totalPrincipalPaid < loan)
93         monthDefault = i
94     end
95
96     # No more payments to add to the schedule
97     break
98
99 else
100    # Deal with normal schedule
101    schedule[i, :monthlyPayment] = installment
102    schedule[i, :totalPandI]     = schedule[i - 1, :totalPandI] + installment
103    schedule[i, :totalI]        = schedule[i - 1, :totalI]      + accruedInterest
104    schedule[i, :totalP]        = schedule[i - 1, :totalP]      + installment - accruedInterest
105 end
106 end
107
108 # At this point schedule[, :monthlyPayment] contains the schedule of all payments, but needs to
109 # include the initial loan.
110 schedule[1, :monthlyPayment] = -loan
111
112 if (showSchedule)
113     print(schedule)
114 end
115
116 cashFlow = schedule[:, :monthlyPayment]
117
118 NPV = function(interest)
119     t = 0:(length(cashFlow) - 1)
120     return sum(cashFlow ./ (1 + interest) .^ t)
121 end
122
123 rootInterest = try
124     round(12 * find_zero(NPV, (-0.9, 1.0), Bisection(); xatol = 0.000001); digits = 4)
125     catch e
126         NaN
127     end
128
```

```

129     return(
130         loanID = loanNumber,
131         IRR = rootInterest,
132         monthDefault = monthDefault
133     )))
134 end
135
136
137 ##
138 ## Calculate the IRR and repayment schedule of a particular loan identified by its loanID
139 function loanNumberIRR(loanNumber)
140     l = lc[ lc[:, :Column1] .== loanNumber, :]
141     global lc
142     calculateIRR(loanNumber = l[1, :Column1],
143                 loan = l[1, :funded_amnt], intRate = l[1, :int_rate], term = l[1, :tenor],
144                 totalPaid = l[1, :total_pymnt], totalPrincipalPaid = l[1, :total_rec_prncp],
145                 totalInterestPaid = l[1, :total_rec_int],
146                 recoveries = l[1, :recoveries], lateFees = l[1, :total_rec_late_fee],
147                 showSchedule = true)
148 end
149
150
151 #####
152 ##
153 ## Quick check
154 ##
155 calculateIRR(loanNumber = 1, loan = 5600, intRate = 0.1299, term = 36,
156                 totalPaid = 6791.72, totalPrincipalPaid = 5600, totalInterestPaid = 1191.72,
157                 recoveries = 0, lateFees = 0,
158                 showSchedule = true)
159
160 calculateIRR(loanNumber = 1, loan = 35000, intRate = 0.1820, term = 60,
161                 totalPaid = 26600.1, totalPrincipalPaid = 3874.72, totalInterestPaid = 5225.38,
162                 recoveries = 17500, lateFees = 0.0,
163                 showSchedule = false)
164
165 calculateIRR(loanNumber = 1734666, loan = 35000, intRate = 0.0797, term = 36,
166                 totalPaid = 1057.04, totalPrincipalPaid = 863.83, totalInterestPaid = 193.72,
167                 recoveries = 0, lateFees = 0,
168                 showSchedule = false)
169
170
171
172
173 ##
174 ## Look for the loans which have gone to their end
175 ##
176 indextmp = (lendingClub.loan_status .== "Fully Paid") .|
177             (lendingClub.loan_status .== "Charged Off") .|

```

```

178     (lendingClub.loan_status .== "Does not meet the credit policy. Status:Charged Off") .|
179     (lendingClub.loan_status .== "Does not meet the credit policy. Status:Fully Paid")
180
181 ## Create the dataset we will use - Should be the same as lending_club_reformatted_paid.rds
182 lc = lendingClub[indextmp, :]
183
184 ## Select relevant variables to calculate profitability
185 ## Column1 contains the loanID's
186 cols = [:Column1, :funded_amnt, :int_rate, :term,
187         :total_pymnt, :total_rec_prncp, :total_rec_int,
188         :recoveries, :total_rec_late_fee]
189
190 lc = select(lc, cols)
191
192 ## Interest rates as percentage
193 lc[:, :int_rate] = lc[:, :int_rate] ./ 100
194
195 ## Create a new column
196 lc[:tenor] = 0
197
198 ## that will record the official loan tenor as a number (instead of string)
199 lc[startswith.( lc[:, :term], " 36"), :tenor] .= 36
200 lc[startswith.( lc[:, :term], " 60"), :tenor] .= 60
201
202 ## New data frame to store the results
203 IRR_Result = DataFrame(loanID = zeros(Int64, nrow(lc)),
204                         IRR = zeros(Float64, nrow(lc)),
205                         monthDefault = zeros(Int64, nrow(lc)))
206
207
208 # ~150 sec. to do the whole dataset
209 @time for i in 1:nrow(lc)
210     global IRR_Result
211
212     # Use multiple-return-value
213     (IRR_Result[i, :loanID], IRR_Result[i, :IRR], IRR_Result[i, :monthDefault]) =
214     calculateIRR(
215         loanNumber = lc[i, :Column1],
216         loan = lc[i, :funded_amnt], intRate = lc[i, :int_rate], term = lc[i, :tenor],
217         totalPaid = lc[i, :total_pymnt], totalPrincipalPaid = lc[i, :total_rec_prncp],
218         totalInterestPaid = lc[i, :total_rec_int],
219         recoveries = lc[i, :recoveries], lateFees = lc[i, :total_rec_late_fee],
220         showSchedule = false)
221 end
222
223
224 IRR_Result[1:10,:]
225 # Check
226 loanNumberIRR(171)

```

```

227
228 CSV.write("datasets/loanIRR.csv", IRR_Result)

```

### 3.4.2.2 Credit margins

```

1 #####
2 ##
3 ## Prepare datasets
4 ##
5
6 ## Previously saved from R with:
7 ##     lending_club <- readRDS("lending_club.rds"); write.csv(lending_club, "lending_club.rds")
8 ##
9 ## WARNING: 1.7GB on disk
10 ##
11 using CSV
12 lendingClub = CSV.read("datasets/lending_club.csv"; delim = ",")
13
14
15 #####
16 ##
17 ##
18 ## CREDIT MARGIN
19 ##
20 ## This method of approximating the credit margin is far less sophisticated than what FI's do.
21 ##
22 ## We need to calculate what the credit margin should be on a defaulted loan to get a nil NPV.
23 ##
24 ## On a risk free loan the CF will be P+I at risk-free on _both_ borrowing and lending sides.
25 ##
26 ## On a defaulted loan, the CF will be:
27 ##     borrowing unchanged = P&I at risk-free
28 ##     and
29 ##     lending P&I at (risk-free + credit margin) until before default, then recoveries+fees.
30 ##
31 ## The principal amortisation profile depends on the credit margin used. We will arbitrarily use
32 ## 20% which is a conservative assumption.
33 ##
34 ## credit risk on that CF should be nil with the right margin when discounted at risk-free.
35 ##
36 ## The function is very similar to the IRR calculation.
37 ##
38
39 using DataFrames, Roots
40
41 # number of monthly payments to model
42 # It exceeds 60 months in case recoveries on a 60-month loan takes the schedule after 60 months.
43 const nMonths = 90
44

```

```

45
46
47 # Sculpt credit foncier profiles over 36 and 60 months at 20% per annum.
48 # The profile is expressed as percentage of loan amount
49 function CreateCreditFoncier(;n = 36, riskFree = 0.0)
50
51     instalment = 1 * riskFree/12 * 1 / (1 - 1 / (1 + riskFree/12) ^ n)
52
53     # We create a schedule
54     schedule = DataFrame(month = 0:nMonths, payment = 0.0)
55
56     # Add the day 1 principal outlay
57     schedule[1, :payment] = -1
58     schedule[2:(n+1), :payment] = instalment
59
60     return(schedule)
61 end
62
63
64 # Solve for the credit margin
65 function CreditMargin(; loanNumber = 1, loan = 1000.0, intRate = 0.05, term = 36,
66     totalPaid = 1000.0, totalPrincipalPaid = 700.0, totalInterestPaid = 50.0,
67     recoveries = 0.0, lateFees = 0.0,
68     riskFree = 0.01,
69     showSchedule = false)
70
71     # Months after which a loan defaults (normal tenor if no default or early prepayment)
72     monthDefault = term
73
74     # Monthly instalment
75     instalment = ceil(loan * intRate/12 / (1 - 1 / (1 + intRate/12) ^ term), digits = 2)
76
77     # Create a blank schedule
78     schedule = DataFrame(month = 0:nMonths, monthlyPayment = 0.0,
79                           principalPayment = 0.0,
80                           totalPandI = 0.0, totalI = 0.0, totalP = 0.0)
81
82     for i in 2:(nMonths + 1)
83         # Get situation at the end of previous month
84         previousTotalPandI = schedule[i - 1, :totalPandI]
85         previousTotalP = schedule[i - 1, :totalP]
86         previousTotalI = schedule[i - 1, :totalI]
87
88         # This is the beginning of a new month. First and foremost, the borrower is expected to pay the
89         # accrued interest on amount of principal outstanding.
90         # The instalment is expected to cover that amount of interest and the rest goes to
91         # reducing the principal due outstanding.
92         accruedInterest = ceil((loan - previousTotalP) * intRate/12; digits = 2)
93         decreasePrincipal = instalment - accruedInterest

```

```

94
95 # If that amount takes the schedule above the total amount of interest shown in the data set,
96 # we should stop the schedule at this point
97 # This is a shortcut since we could have a payment higher than the interest due, but not enough
98 # to cover the expected principal repayment. However, it works well in practice.
99 if previousTotalI + accruedInterest > totalInterestPaid
100
101     # We stop the normal schedule at this date.
102     # Interest is paid (although less than scheduled)
103     schedule[i, :monthlyPayment] = totalInterestPaid - previousTotalI
104
105     # Whatever principal is left as per the dataset
106     schedule[i, :monthlyPayment] += totalPrincipalPaid - previousTotalP
107
108     # Then 3-month after the last payment date, recoveries and and later fees are paid
109     schedule[i + 3, :principalPayment] += recoveries + lateFees
110
111     # Not really useful, but for completeness
112     schedule[i, :totalPandI] = totalPaid
113     schedule[i, :totalI]      = totalInterestPaid
114     schedule[i, :totalP]      = totalPrincipalPaid
115
116     # If total principal paid is less than borrower, then it is a default, and the monthDefault
117     # is adjusted.
118     if (totalPrincipalPaid < loan)
119         monthDefault = i
120     end
121
122     # No more payments to add to the schedule
123     break
124
125 else
126     # Deal with normal schedule
127     schedule[i, :monthlyPayment] = instalment
128     schedule[i, :principalPayment] = decreasePrincipal
129     schedule[i, :totalPandI]      = schedule[i-1, :totalPandI] + instalment
130     schedule[i, :totalI]          = schedule[i-1, :totalI]      + accruedInterest
131     schedule[i, :totalP]          = schedule[i-1, :totalP]      + decreasePrincipal
132 end
133 end
134
135 # At this point schedule[, :monthlyPayment] contains the schedule of all payments, but needs to
136 # include the initial loan.
137 schedule[1, :principalPayment] = -loan
138
139 if (showSchedule)
140     println("Payments")
141     println(schedule)
142 end

```

```

143
144 # Principal profile on the borrowing side
145 creditFoncier = round.(CreateCreditFoncier(n = term, riskFree = riskFree)[:, :payment] .* loan;
146                               digits = 2)
147
148 # For a given margin, calculate the _net_ NPV between the what is borrowed at the risk-free rate
149 # and what is earned on the loan principal profile (possibly shortened because of default)
150 # carrying an interest of risk-free + credit margin
151 function NetNPV(margin)
152     # We need to store the calculated interest
153     interestSchedule = DataFrame(month = 0:nMonths, interestPayment = 0.0)
154
155     # For each month, calculate the amount of interest with the credit margin
156     for i in 2:(monthDefault + 1)
157         outstandingPrincipal = sum(schedule[1:(i - 1), :principalPayment])
158         interestSchedule[i, :interestPayment] =
159             -round((riskFree + margin)/12 * outstandingPrincipal; digits = 2)
160     end
161
162     # Net final cashflow is:
163     #      total principal and interest cashflow on the lending side
164     # less
165     #      borrowing profile
166     cashFlow = schedule[:, :principalPayment] .+ interestSchedule[:, :interestPayment]
167     cashFlow = cashFlow .- creditFoncier
168
169     return sum(cashFlow ./ (1 + riskFree/12) .^ (0:nMonths))
170 end
171
172 # rootInterest = round(find_zero(NetNPV, (-0.5, 10), Bisection()); digits = 6)
173 rootInterest = try
174     rootInterest = round(find_zero(NetNPV, (-0.5, 10), Bisection()); digits = 6)
175 catch e
176     NaN
177 end
178
179
180 return(
181     loanID = loanNumber,
182     creditMargin = rootInterest,
183     monthDefault = monthDefault
184 ))
185 end
186
187
188 #####
189 ##
190 ## Quick check
191 ##

```

```

192 CreditMargin(loanNumber = 1, loan = 5600, intRate = 0.1299, term = 36,
193     totalPaid = 6791.72, totalPrincipalPaid = 5600, totalInterestPaid = 1191.72,
194     recoveries = 0, lateFees = 0,
195     riskFree = 0.02, showSchedule = false)
196
197 CreditMargin(loanNumber = 1, loan = 35000, intRate = 0.1820, term = 60,
198     totalPaid = 26600.1, totalPrincipalPaid = 3874.72, totalInterestPaid = 5225.38,
199     recoveries = 17500, lateFees = 0.0,
200     riskFree = 0.02, showSchedule = true)
201
202 CreditMargin(loanNumber = 1734666, loan = 35000, intRate = 0.0797, term = 36,
203     totalPaid = 1057.04, totalPrincipalPaid = 863.83, totalInterestPaid = 193.72,
204     recoveries = 0, lateFees = 0,
205     riskFree = 0.02, showSchedule = true)
206
207
208 ##
209 ## Look for the loans which have gone to their end
210 ##
211 indextmp = (lendingClub.loan_status == "Fully Paid") .|
212     (lendingClub.loan_status == "Charged Off") .|
213     (lendingClub.loan_status == "Does not meet the credit policy. Status:Charged Off") .|
214     (lendingClub.loan_status == "Does not meet the credit policy. Status:Fully Paid")
215
216 ## Create the dataset we will use - Should be the same as lending_club_reformatted_paid.rds
217 lc = lendingClub[indextmp, :]
218
219 ## Select relevant variables to calculate profitability
220 ## Column1 contains the loanID's
221 cols = [:Column1, :funded_amnt, :int_rate, :term,
222         :total_pymnt, :total_rec_prncp, :total_rec_int,
223         :recoveries, :total_rec_late_fee]
224
225 lc = select(lc, cols)
226
227 ## Interest rates as percentage
228 lc[!, :int_rate] = lc[!, :int_rate] ./ 100
229
230 ## Create a new column
231 lc[:tenor] = 0
232
233 ## that will record the official loan tenor as a number (instead of string)
234 lc[startswith.( lc[!, :term], " 36"), :tenor] .= 36
235 lc[startswith.( lc[!, :term], " 60"), :tenor] .= 60
236
237 ## New data frame to store the results
238 creditMargin_Result = DataFrame(loanID = zeros(Int64, nrow(lc)),
239                                 creditMargin = zeros(Float64, nrow(lc)),
240                                 monthDefault = zeros(Int64, nrow(lc)))

```

```

241
242
243 # ~150 sec. to do the whole dataset
244 @time for i in 1:nrow(lc)
245   global creditMargin_Result
246
247 # Use multiple-return-value
248 # 1h17m runtime
249 (creditMargin_Result[i, :loanID],
250  creditMargin_Result[i, :creditMargin],
251  creditMargin_Result[i, :monthDefault]) =
252   CreditMargin(
253     loanNumber = lc[i, :Column1],
254     loan = lc[i, :funded_amnt], intRate = lc[i, :int_rate], term =lc[i, :tenor],
255     totalPaid = lc[i, :total_pymnt], totalPrincipalPaid = lc[i, :total_rec_prncp],
256     totalInterestPaid = lc[i, :total_rec_int],
257     recoveries = lc[i, :recoveries], lateFees = lc[i, :total_rec_late_fee],
258     riskFree = 0.02,
259     showSchedule = false)
260 end
261
262
263 creditMargin_Result[1:10,:]
264
265 CSV.write("datasets/CreditMargins.csv", creditMargin_Result)

```

### 3.5 System version

```

1 ##                               sysname
2 ##                               "Linux"
3 ##                               release
4 ##                               "5.3.0-21-generic"
5 ##                               version
6 ## "#22-Ubuntu SMP Tue Oct 29 22:55:51 UTC 2019"
7 ##                               nodename
8 ##                               "x260"
9 ##                               machine
10 ##                              "x86_64"
11 ##                               login
12 ##                               "unknown"
13 ##                               user
14 ##                               "emmanuel"
15 ##                               effective_user
16 ##                               "emmanuel"

```

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