Creditor ----(% interest)---- Lender, banks make profit out of this interest rate

What is a credit risk?

- The likelihood that a borrower would not repay their loan to lender
- When a borrower fails to replay loan
- The lender will have to sustain substantial cost in an effort to recover outstanding debt - called collection cost

Risk based pricing

- Based on credit risk associated with the particular client, banks decide the % interest rate and size of the collateral
- Lending to borrowers with high probability default is one of the main reasons of financial crisis. Example 2008,
  - Factor - high default rate of sub-prime mortgages; low interest rate; loans were provided with 100% or more value of the home; demand for homes increased -> selling rice increased
  - Mortgage backed securities lost value
  - Big banks holding this instruments got affected - Le Mans Brother

Regulatory rule

- Lender must assess credit risk associated with each borrower
- Lenders know certain amount of credit risks is always associated with each/every client
- It is important to estimate expected loss - amt of money a lender lose by lending to a borrower.
- There are many models, but established credit risk model has 3 components
  - PD (Probability of default)
  - LGD (Loss given default)
  - EAD (Exposure at default)

PD (Probability of default):

- The borrower inability to repay his/her debt in full or on-time
- Estimate of a borrower to likelihood the borrower will default

Loss given default (LGD)

- Loss of an asset due to borrowers' default
- The proportion of the total exposure that cannot be recovered by the lender once a default has occurred

EAD (Exposure at default)

- Total value that a lender is exposed to when a borrower defaults i.e. maximum amount that a bank can lose if a borrower defaults
  Example: A borrower wants to buy a house
  Price = $500,000
  (Agreement) Bank funds 80% (loan to value) = $400,000
  Borrower repaid = $40,000
  Outstanding balance = $400,000 - $40,000 = $360,000
  When a borrower defaults, total value that a lender is exposed to is $360,000. This is **Exposure at default.**
  Assume that the banks can sell the house is at $342,000, then
  Loss given default = (EAD - $342,000)/EAD
  - Assume that there is an empirical evidence that one in four homeowners have defaulted
    - PD = 1/4
  - Expected Loss (EL) = PD * LGD * EAD, i.e. 25% * 5% * $360,000 = $4,500

<u>Capital Adequacy/Regulations and Basel III accord</u>

- Govt. regulators impose certain requirements for banks to make sure bank conduct their business without risking the stability of the economy system
- Regulators set rules
  - Regulate bank operations & hence reduce bank risky behaviour
  - Guarantee to the public that banking system is in good health

- Capital Adequacy: Banks require to hold sufficient capital to absorb capital losses from default. This obligation is called "Capital Requirement"
- CAR(Capital Adequacy ratio) = Capital / Risk-weighted assets (loans)
- Basel III accord - primary objective is to ensure capital allocation. Greater the risk the bank exposed to greater amount of capital it needs to hold
    - Three pillars of Basel III -
        - Market discipline
        - Supervisory review
        - **Minimum Capital Requirement**
          Two approaches
            1. Standardized approach
            2. Internal ratings based approach (IRB)
                - Foundation internal rating based (F-IRB)
                - Advanced internal rating based (A-IRB)
- Basel III accord prescribes regulators should allow banks to choose from 3 different approaches to calculate/modelling credit risk i.e. calculating & modelling each of the three components of expected loss
    - Standardized approach
    - Foundation internal rating based (F-IRB)
    - Advanced internal rating based (A-IRB)
- Capital requirements are calculated differently in 3 approaches

	SA	F-IRB	A-IRB
PD	External data	Internally calculated	Internally calculated
LGD	External data	External data	Internally calculated
EAD	External data	External data	Internally calculated

    - External data comes from credit rating agencies such as FICO, S&P, Moody's, Fitch (for firms)
    - Two major credit reporting agency that collects data from FICO
    - Equifax
    - TransUnion
    - Credit score ranges from 300 to 800
    - For firms, credit cards & consumer loans, banks should hold around 75% of the total exposure * CAR (Capital adequacy ratio)
    - For secured residential property, banks should hold around 35% of the total exposure * CAR (Capital adequacy ratio)

- The more precise banks estimate expected -- Less capital is needed to hold -- more new business bank can generate

- IRB approaches
    - Allows bank to establish their own credit rating
    - Precise calculations about the held capital for each individual exposure
    - Allocate resources to cover losses
    - Be more profitable

- Characteristics of the data for individual clients

Biological info	External data	Characteristic of data
Age Sex Marital status	Credit rating No. of recent enquiries	Fix term consumer loan Life-span of product Purpose of the loan

Education Income Zip-code		Interest rate

- Credit limit utilization - the proportion of money spent on the credit card

Data availability
- Most of the variables are available at time of application
- Many of the variable/information is available after loan is granted & behaviour of the loan borrower can be obtained for long sufficient

Application models	Behaviour models
Most of the variables are available at time of application	Most of the variables are available at time of application Many of the variable/information is available after loan is granted & behaviour of the loan borrower can be obtained for long sufficient

- Behaviour model is used to calculate probability of default or expected loss after loan is granted
- If a customer holds credit card, banks can use behaviour model to grant or reject loan application

Understanding the data
- Dependent variables
- Independent variables - predictor/features

PD model : Logistic regression
- Non-statistically savvy user example: front office workers, present in a simplified manner such as score cards
  LGD model: Beta regression
- How much loan has been recovered after the client defaulted?
  EAD model: Beta regression

Different data types
- Discrete
- Continuous
  Based on data types data-preprocessing technique varies

Distinctive feature of PD model is all the independent variables have to be categorical - the reason is that it is much easier to present a model in a simplified form and turn into score card - we transform all the independent variable into categorical variable/dummy variable

Fine Classing: We slice the independent variable into equally sized intervals or classes
Coarse classing: we find how well each of the intervals discriminate b/w defaulted and non-defaulted. If two adjacent discrete variables discriminate each other very well, then we can merge them.

PD Model
- Established dependent variable
- Binary
  - 0 = Bad loan
  - 1 = Good loan
- "Default definition": If a borrower is more than 90 days past due on a loan
- Statistical methodology to model PD is a logistic regression where dependent variable is whether a customer is defaulter or not
- Logistic regression estimates the relationships b/w 2 things

- Odds of an outcome (dependent variable) --- linear combination (Independent ∑variable) of predictors
- Logistic regression
  - ln(Non-default/default) = ∑βjXj = β0 + β1X1 +β2X2 + ……βnXn

- "**Weight of evidence**" - The ability of each category to predict the dependent variable.
  - To what extent an independent variable would predict a dependent variable
  - ln(%Good/%Bad)

Variable Categories	Good	Bad	Proportion of good	Proportion of bad	Weight of evidence
Higher education	4000	600	4000/16000 =25%	600/4000 = 15%	ln(25/15) = 0.51
No Higher education	12000	3400	12000/16000 = 75%	3400/4000 =85%	ln(75/85) = -0.13
Total	16000	4000			

- "**Information value**" - shows how much information the original independent variable brings with to explaining the dependent variable

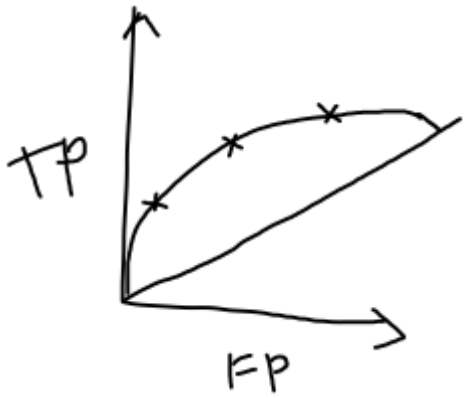
Range 0 - 1	Predictive power
IV < 0.02	No predictive power
0.02 <= IV =< 0.1	Weak predictive power
0.1 <= IV =< 0.3	Medium predictive power
0.3 <= IV =< 0.5	Strong predictive power
0.05 < IV	Suspiciously high, too good to be true

Variable Categories	Good	Bad	Proportion of good	Proportion of bad	Weight of evidence	%good-%bad	Information Value
Higher education	4000	600	4000/16000 =25%	600/4000 = 15%	ln(25/15) = 0.51	0.25-0.15 = 0.1	0.51*0.1 =0.0511
No Higher education	12000	3400	12000/16000 = 75%	3400/4000 =85%	ln(75/85) = -0.13	0.75-0.85 = -0.1	0.13*0.1 =0.013
Total	16000	4000					0.064 = weak predictive power

- **Overfitting**: A substantial issue we might face when statistical model has focused on a particular dataset so much that it missed the point

- **Underfitting**: is under fitting when model fails to capture the underlying logic of data that is it didn't learn well so it doesn't know what to do and therefore it provides inaccurate answers

- **ROC** - Receiver operating curve



fpr, tpr, thresholds = roc_curve(df_actual_predicted_probs['loan_data_targets_test'], df_actual_predicted_probs['y_hat_test_proba'])
Here we store each of the three arrays in a separate variable.

Interpretation	Area under the curve
Bad	50-60%
Poor	60-70%
Fair	70-80%
Good	80-90%
Excellent	90-100%

from sklearn.metrics import roc_curve, roc_auc_score
AUROC = roc_auc_score(df_actual_predicted_probs['loan_data_targets_test'], df_actual_predicted_probs['y_hat_test_proba'])
Gini = AUROC *2 -1

Population Stability Index

Values of PSI: 0-1	Population difference
PSI = 0	No difference
PSI < 0.1	Little no difference
0.1 > PSI > 0.25	Little difference (no action is taken)
PSI > 0.25	Big difference (Action is taken)
PSI = 1	Absolute difference

LGD and EAD model

Dependent variables
RECOVERY RATE = amt_recovered/total_fund_amt
CREDIT CONVERSION FACTOR = (total_fund_amt - total_rec_principal) / total_fund_amt