IEOR E4650 Business Analytics

Session 2: Lending Analytics
Nomis (B): Analyzing the Value Proposition

Spring 2018

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Today

Nomis (B)

- e-Car data
- Market analysis
- Pricing opportunity

Logistic regression

- Predicting customers' decisions
- Analytics-driven APR

E-Car Data

	A	B	C	D	E	F	G	H	I	J	K	L
1	Tier	FICO	Approve Date	Term	Amount	Previous APR	Car Type	Competition APR	Accept?	APR	Cost of Funds	Partner Bin
2	2	702	7/2/2002	60	22000		U	5.85	0	6.19	1.84	3
3	2	710	7/3/2002	60	21000		U	5.85	0	6.19	1.84	1
4	3	693	7/6/2002	60	19598		U	5.85	1	7.29	1.84	1
5	3	696	7/6/2002	60	23071		U	5.85	0	7.29	1.84	3
6	3	697	7/8/2002	60	21578		U	5.80	1	7.29	1.84	2
7	2	702	7/8/2002	60	20211		U	5.80	1	6.19	1.84	2
8	2	709	7/10/2002	60	21051		U	5.80	1	6.19	1.84	1
9	3	690	7/12/2002	60	21498		U	5.80	0	7.29	1.84	1
10	3	684	7/13/2002	60	18000		U	5.80	1	7.29	1.84	3
11	2	706	7/15/2002	60	24025		U	5.80	0	6.19	1.84	1
12	2	704	7/15/2002	60	23000		U	5.80	0	6.19	1.84	3
13	3	693	7/16/2002	60	19620		U	5.80	1	6.59	1.84	2
14	2	702	7/17/2002	60	24227		U	5.80	1	5.35	1.84	1
15	2	705	7/18/2002	60	21262		U	5.80	0	5.69	1.84	1
16	3	692	7/19/2002	60	25000		U	5.80	0	6.59	1.84	1

- Rows: observations (208,085)
- Columns: variables (12)
  - Categorical variables: tier, car type, accept?, partner bin
  - Continuous variables: FICO, term, amount, competition APR, APR, prime

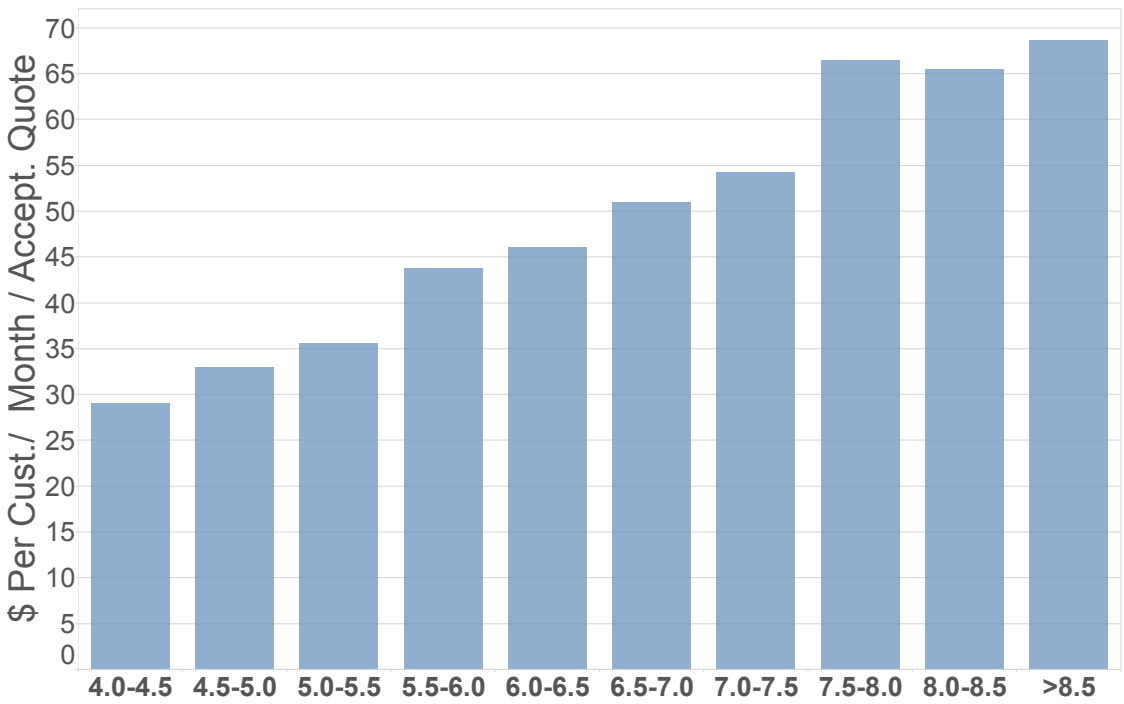
The e-Car Environment: Observations

Net Revenue Analysis: Segment Level

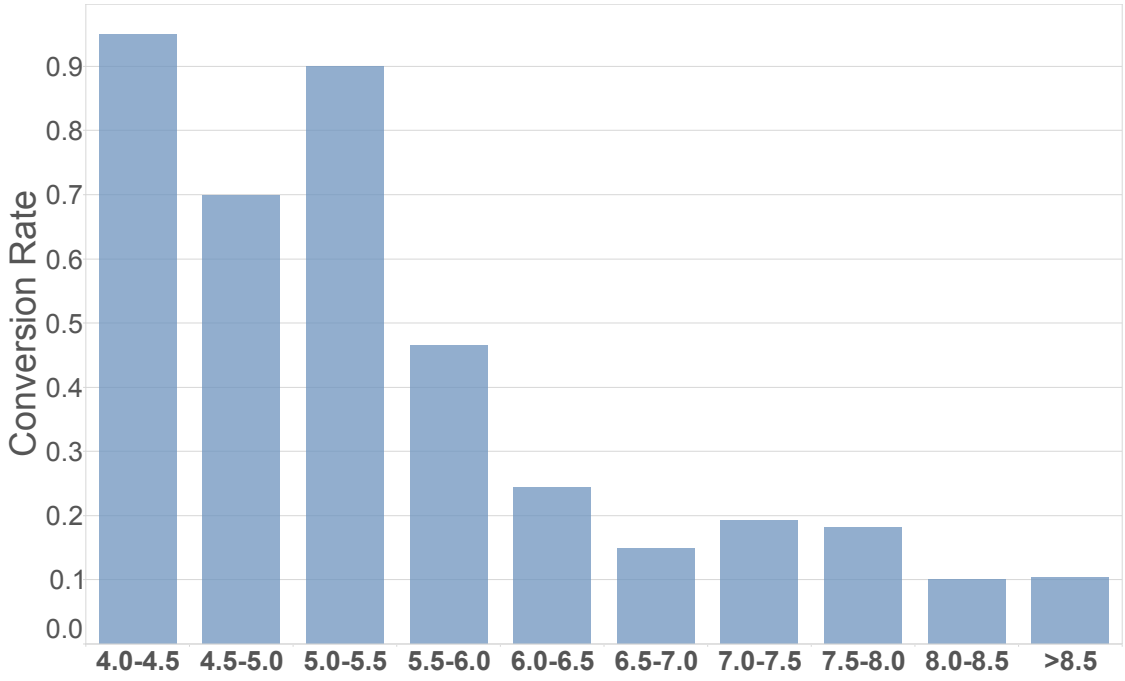
Focus on one segment

- USED cars
- FICO scores 684-712
- Term = 60 months
- Amount between 17.8K and 25K

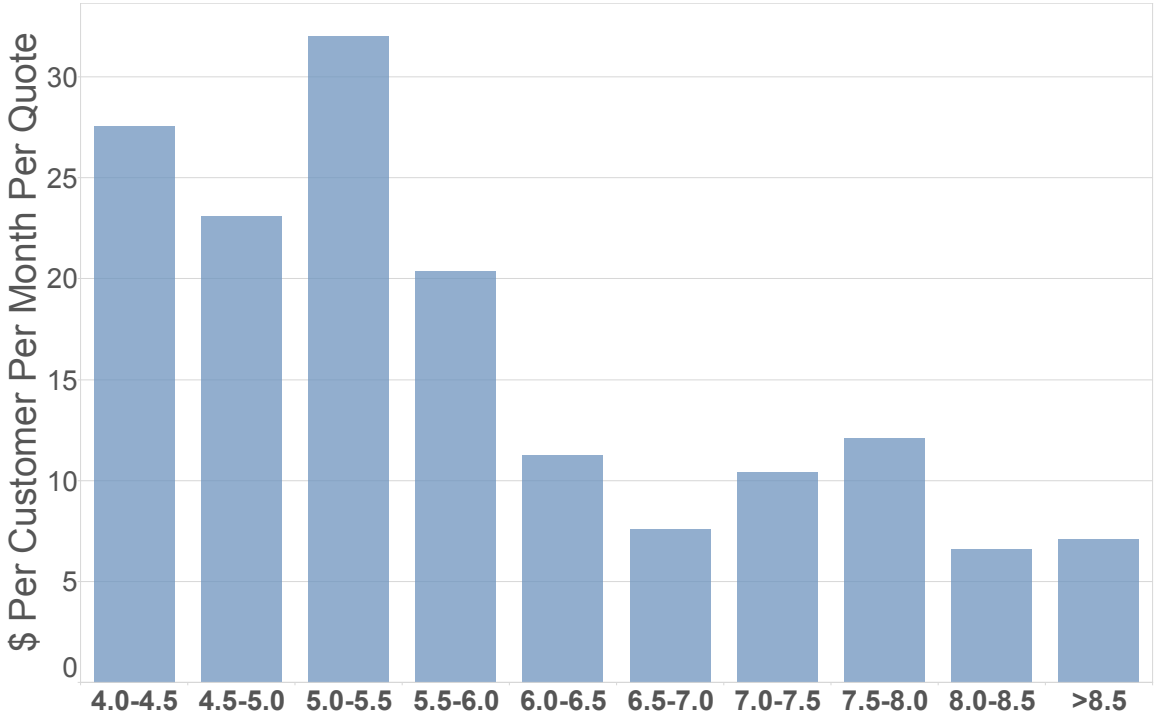
Segment Analysis: Avg Net Rev per Cust per Month per Accepted Quote vs. APR



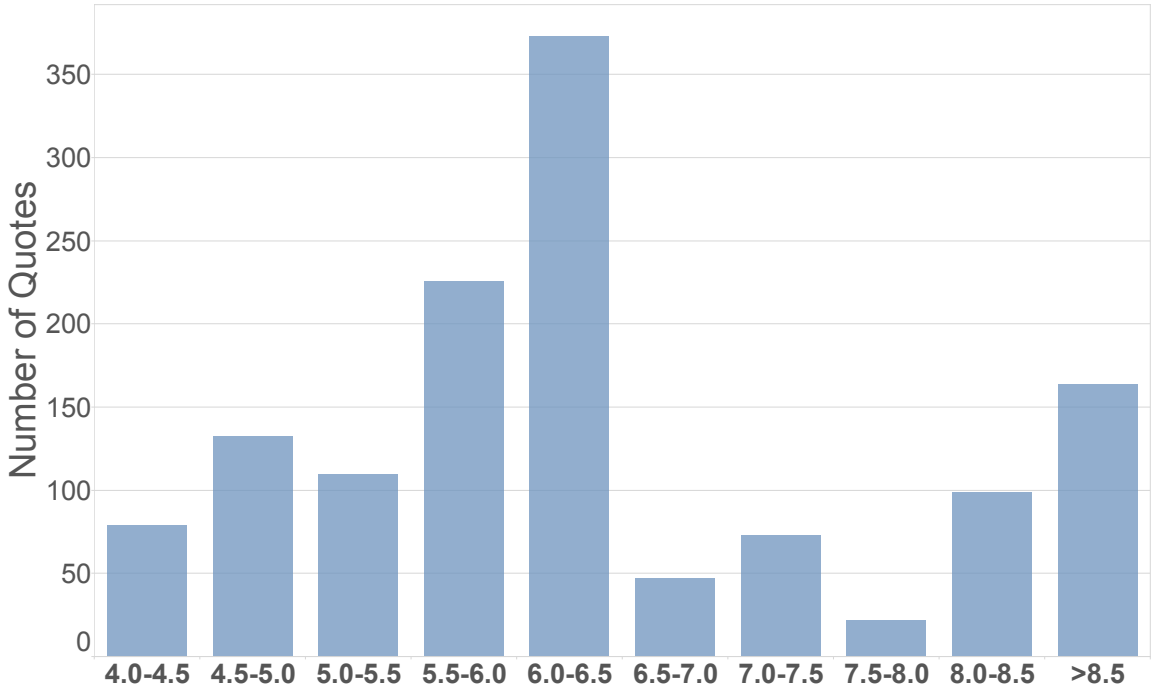
Segment Analysis: Conversion Rate versus APR



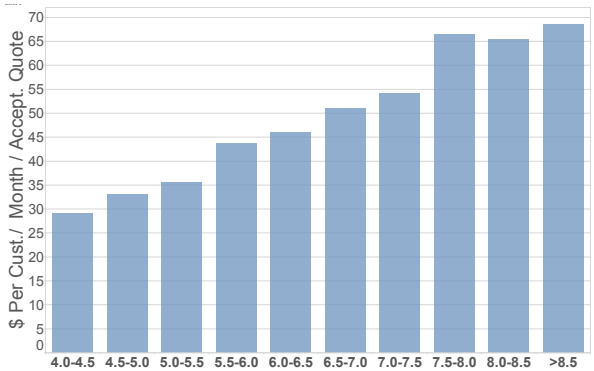
Segment Analysis: Average Net Revenue vs. APR

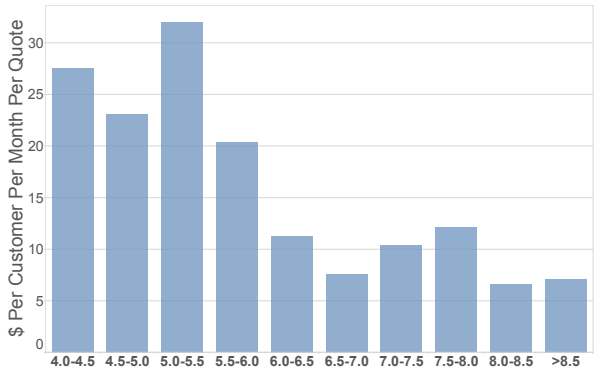


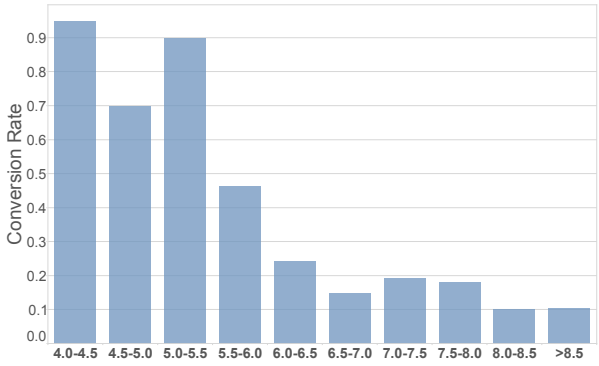
Segment Analysis: APR Quoted (Frequency)

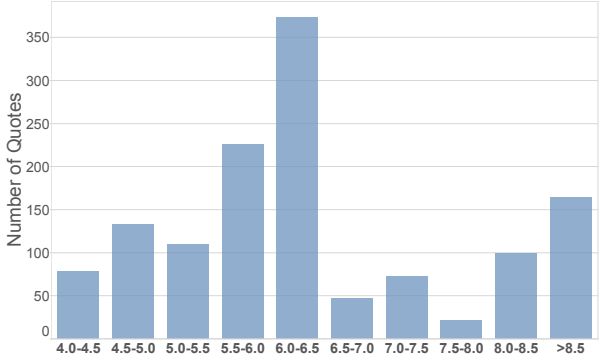


Segment Analysis









From Data to Decisions

The Goal

Data available for 208,085 past customer interactions:

- customer characteristics (FICO)
- loan characteristics (amount, term)
- APR quotes
- responses (accept / reject)

Goal: Find the "best" APR to set for future customers

Framing the Problem

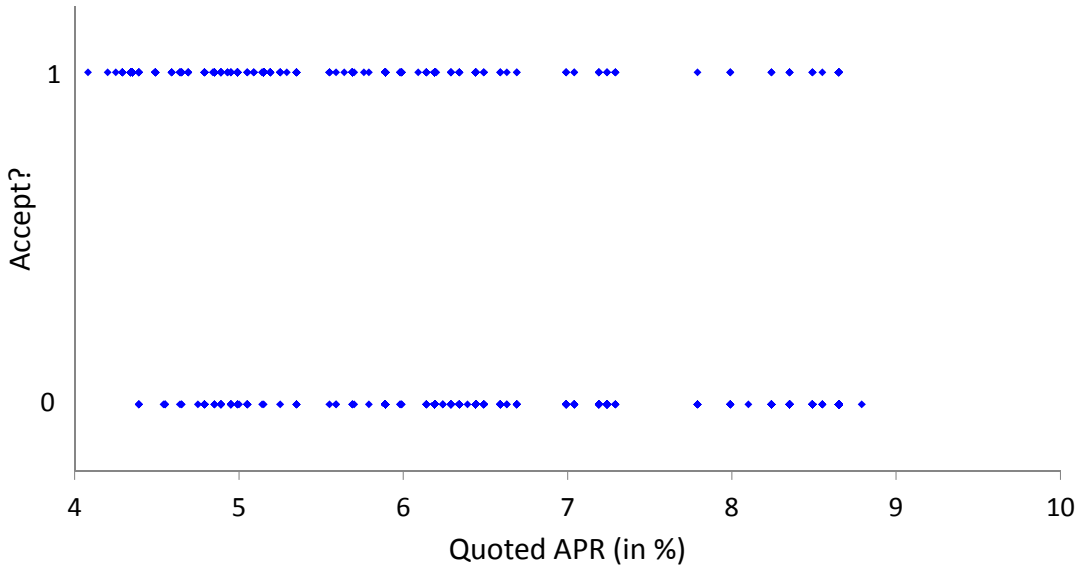
Maximize

(Net Revenue for loan) $\times$ (Probability of accept given APR quoted)

Two key inputs:

- Net Revenue
  $\Rightarrow$ calculate from cost information Typically, profit per loan is Net revenue minus adjustment for customer risk
- Prob. of accept given APR quoted
  $\Rightarrow$ need to "predict" customer decisions
  $\rightarrow$ In economic terms, we need to estimate the *demand curve* from the data.

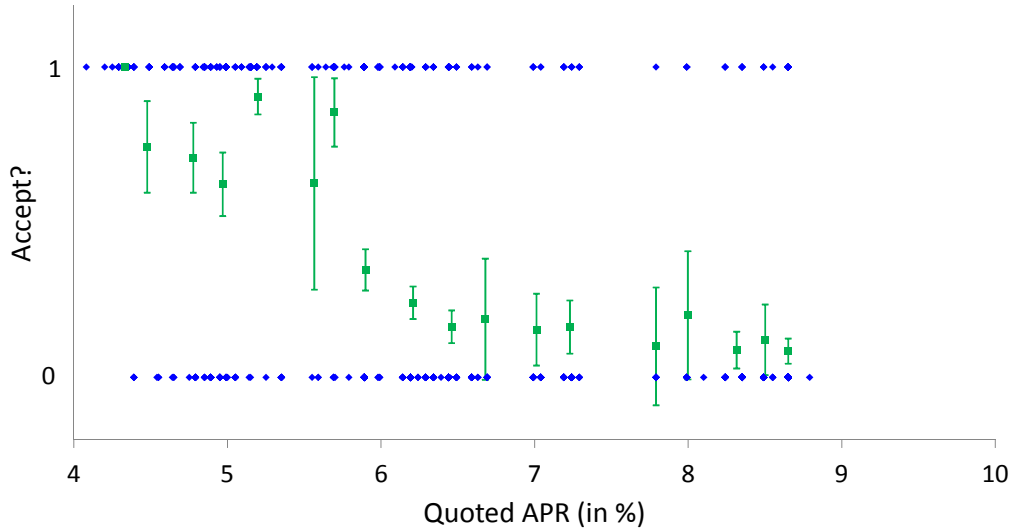
Accept? versus Quoted APR



Illustrative segment for all future analysis

- USED cars, FICO: 684-712
- Term: 60 months, Amount: between 17.8K and 25K

Accept? versus Quoted APR: Bucketed Data



Bucketed data for easier visualization

- APR buckets: 4.125-4.375, 4.375-4.625, etc.
- Average in each bucket plotted with two standard errors

How to Predict "Accept?"

Linear regression

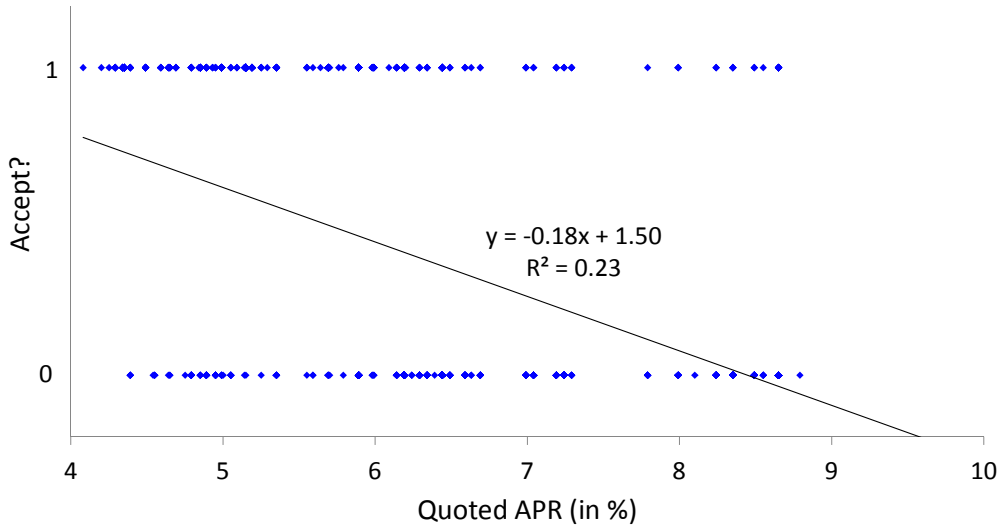
$$\text{Accept}_j = a + b\,\text{APR}_j + \varepsilon_j$$

where APR_j is the APR quoted to customer j and

$$\text{Accept}_j = \begin{cases} 1 & \text{if customer } j \text{ accepted the quote} \\ 0 & \text{otherwise} \end{cases}$$

- Focus on a given profile of customer / loan characteristics (FICO bucket, loan term, amount bucket)
- Linear regression allows loan acceptance to vary with the quoted rate

Accept? versus Quoted APR: Linear Regression



Does this look reasonable?

Accept? versus Quoted APR: Linear Regression

Issues with linear regression

- Response function reflects probabilities: it should be between 0 and 1
- For a binary response variable, there are only two cases
  - Violates the normality assumption
  - Different variance at different levels of quoted APR

Logistic Regression

Logistic regression is a technique for fitting a curve to data in which the dependent variable is binary

Applications

- Response to medical treatment:
  worked (coded as 1) or did not work (coded as 0)
- Customized pricing: bought (1) or not (0)
- Sponsored search: user clicked (1) or did not click (0)

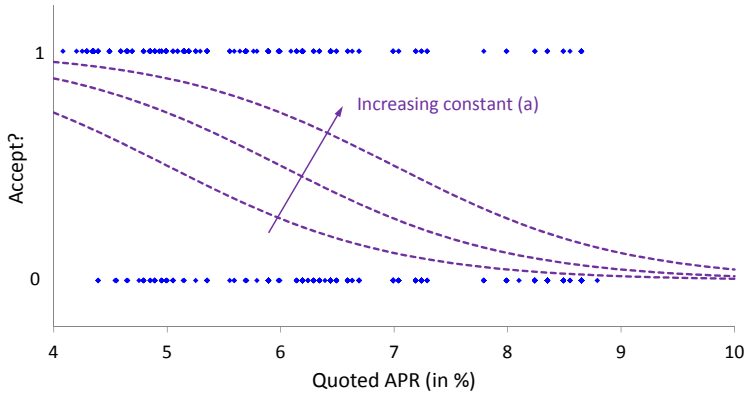
Logistic Regression for Predicting Customer Response

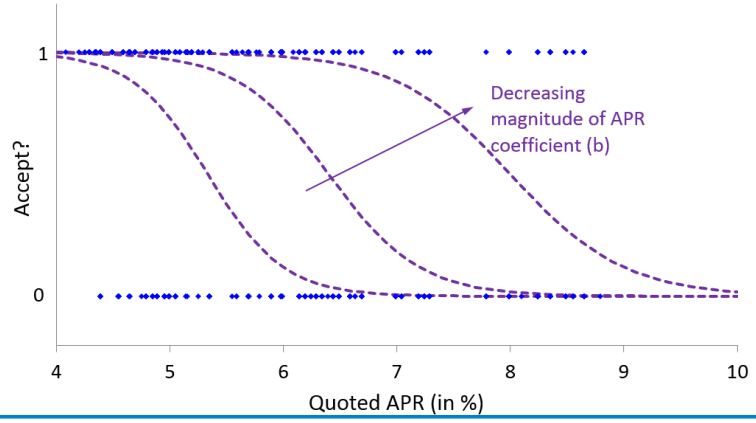
$$\text{Probability of accept given quoted APR} = \frac{\exp(w)}{1+\exp(w)}$$

$$\text{with } w = a + b\,\text{APR}$$

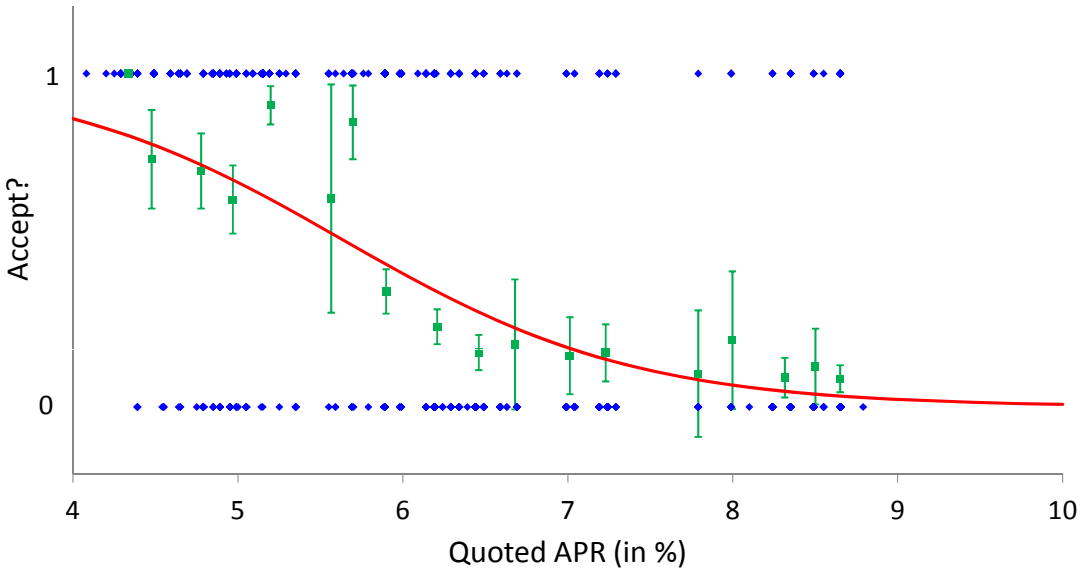
- Always between 0 and 1
- Allows for flexible non-linear shapes
- Parameters a and b need to be estimated based on the data
  pick the parameters that "best" explain the data we have

Logistic Regression: Model Flexibility





Accept? versus Quoted APR: Logistic Regression



Estimating Parameters: Logistic Regression in R

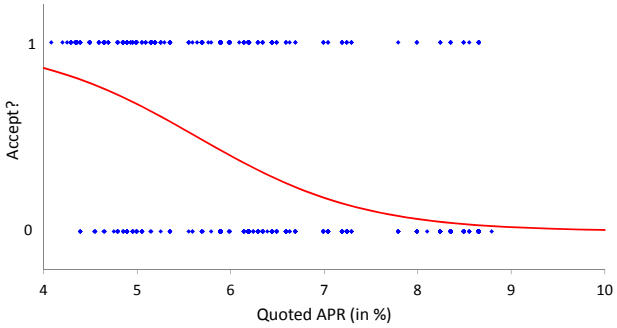
```
>logitReg = glm(Outcome ~ Rate, family = binomial)
>summary(logitReg)
Call:
glm(formula = Outcome ~ Rate, family = binomial)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.8044  -0.8909  -0.3032   0.8859   3.8847

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  6.36032    0.42079   15.12   <2e-16 ***
Rate        -1.12777    0.06973  -16.17   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 2000.3  on 1539  degrees of freedom
Residual deviance: 1572.6  on 1538  degrees of freedom
AIC: 1576.6
Number of Fisher Scoring iterations: 5
```


Logistic Regression Output

Interpreting the output:

Prob. of accept given quoted APR

$$= \frac{\exp(6.36 - 1.13 \times \text{APR})}{1 + \exp(6.36 - 1.13 \times \text{APR})}$$



Moving to Decisions: Setting the APR for Used Car Loans

e-Car's objective: assign "best" rate to each incoming customer

Maximize

$$(\text{Net Revenue}(\text{APR})) \times (\text{Probability accept quoted APR})$$

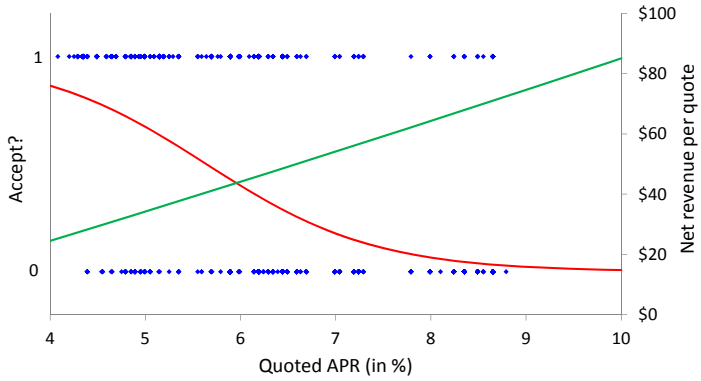
Exercise

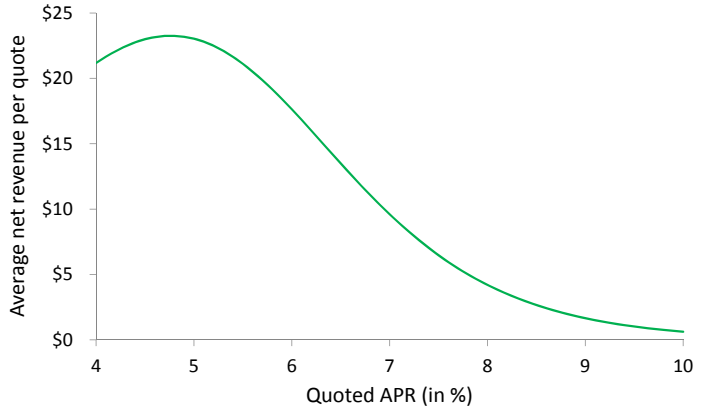
Assume prime = 1.40%, loan amount = \$21,000

Compute expected net revenue per customer per month for:

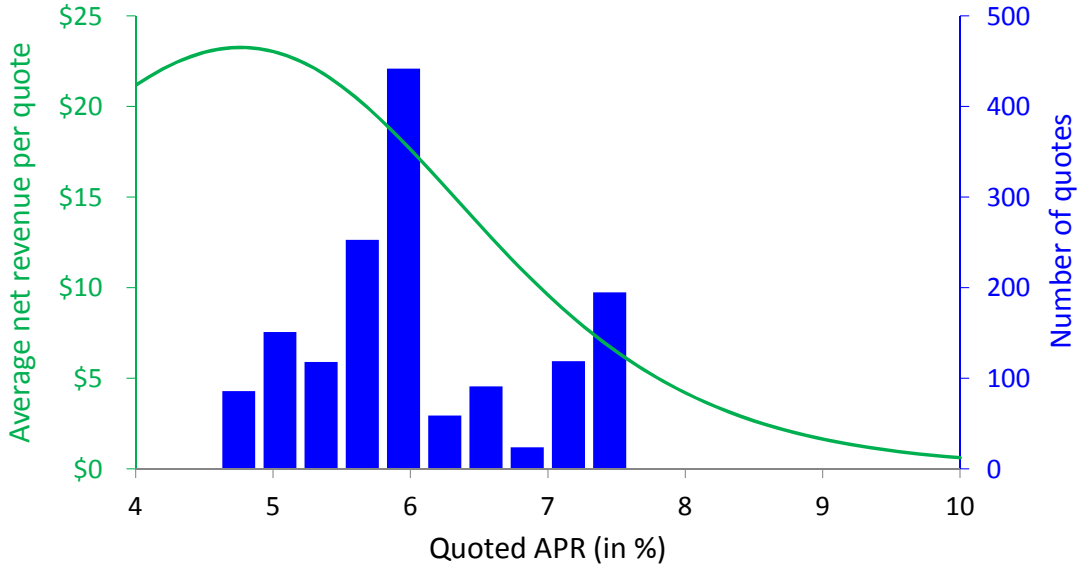
- APR = 6.00 (mode of rates offered in segment)
  Payments per month from customer to e-Car if accept: \$406
  Cost per month to e-Car: \$363
- APR = 4.75 (alternative rate)
  Payments per month from customer to e-Car if accept: \$393
  Cost per month to e-Car: \$363

Average Net Revenue per Quote vs. Quoted APR

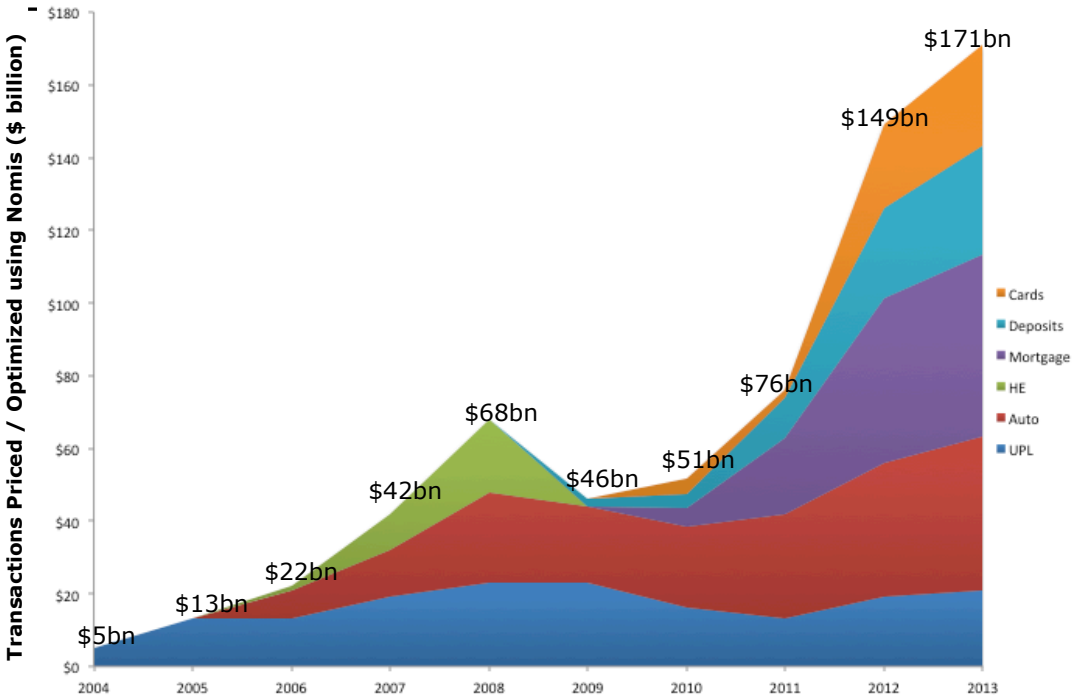




The Opportunity



Nomis Solutions Today



In 2015, more than $1 trillion transactions priced

Logistic Regression: General Formula

In general, there could be multiple independent variables $(x_1, ..., x_k)$ (as in linear regression)

Probability of success given $(x_1, ..., x_k)$ is modeled as

$$p(x_1, ..., x_k) = \frac{\exp(w)}{1 + \exp(w)}$$

$$\text{with } w = a + b_1 x_1 + b_2 x_2 + ... + b_k x_k$$

Parameters $a, b_1, ..., b_k$ need to be estimated

Other Applications of Logistic Regression

Online advertising (e.g., Google / www.google.com)

Business model:

- Sponsored search: cost per click (CPC)
- Key question: what drives clicks (quality of ad,...)

Online Content Recommendations (e.g., Outbrain, Inc. / www.outbrain.com)

Business model:

- Users "sold" from site to another
- Revenue sharing between operator and source publisher
- Key revenue driver of recommendation operator: clicks
- Key question: what drives clicks (context, exploration, clicks of other users, etc.)

Summary

Predictive Analytics

- Attempt to capture and exploit relationships in the data to:
  - Predict customer decisions
  - Improve decision making

Logistic regression

- Model probabilistic behavior of customers with 0/1 outcomes
- Select the parameters that maximize the likelihood of observing the data

Many business models are supported by or rely on predictive analytics