Promoting Financial Products to Bank Customers From a Prescriptive Analytics Perspective

Machine Learning Under a Optimization Lens Final Project

Luca-Andrei Manea, Zeki Yan

MIT Management Sloan School
Operations Research Center

PROBLEM STATEMENT

Prediction

Customer Interests

- Savings account
- Mortgage account
- Pension account

Marketing Channel

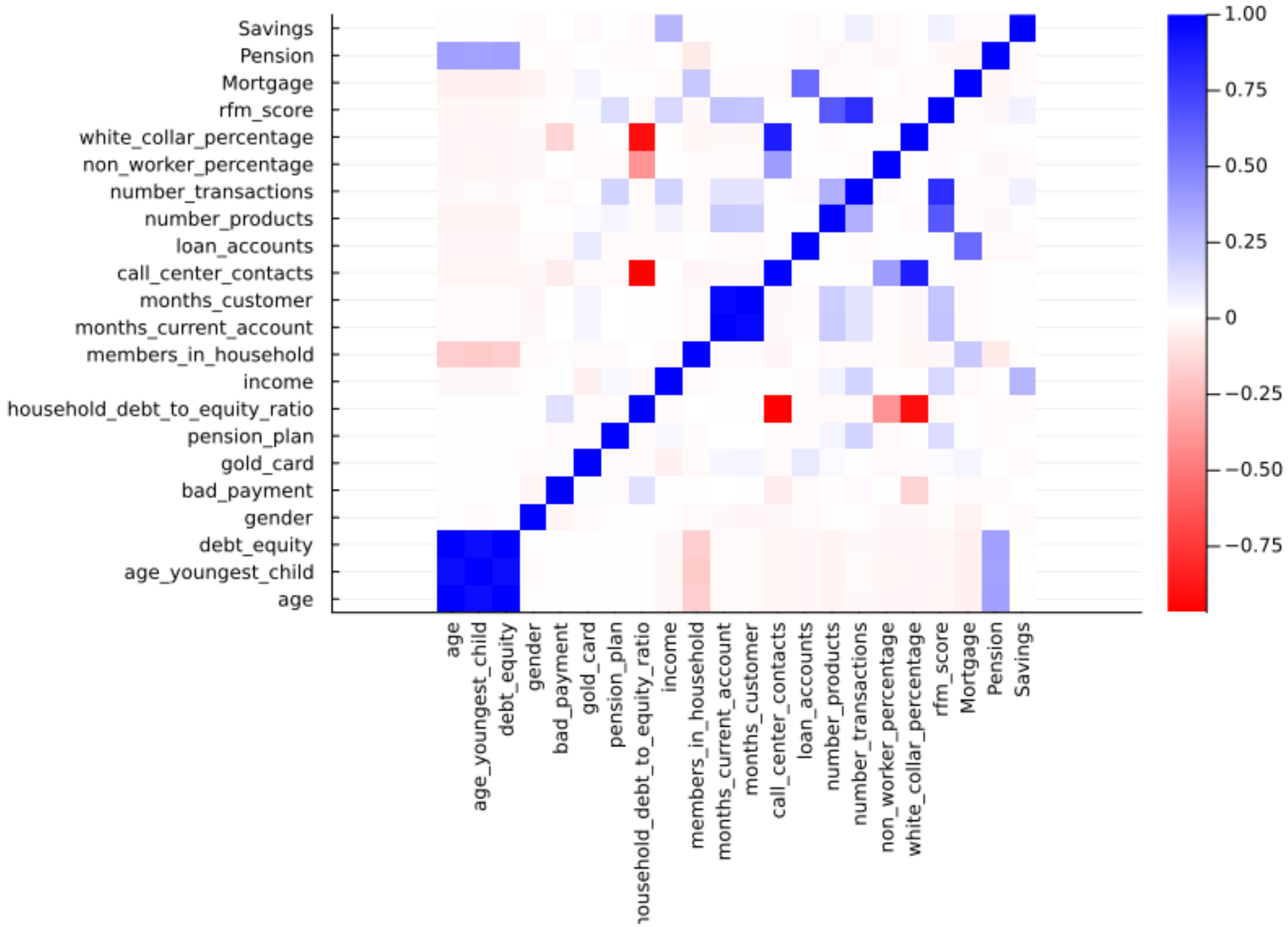
- Gift
- Newsletter
- Seminar

Decision

TO BE DECIDED

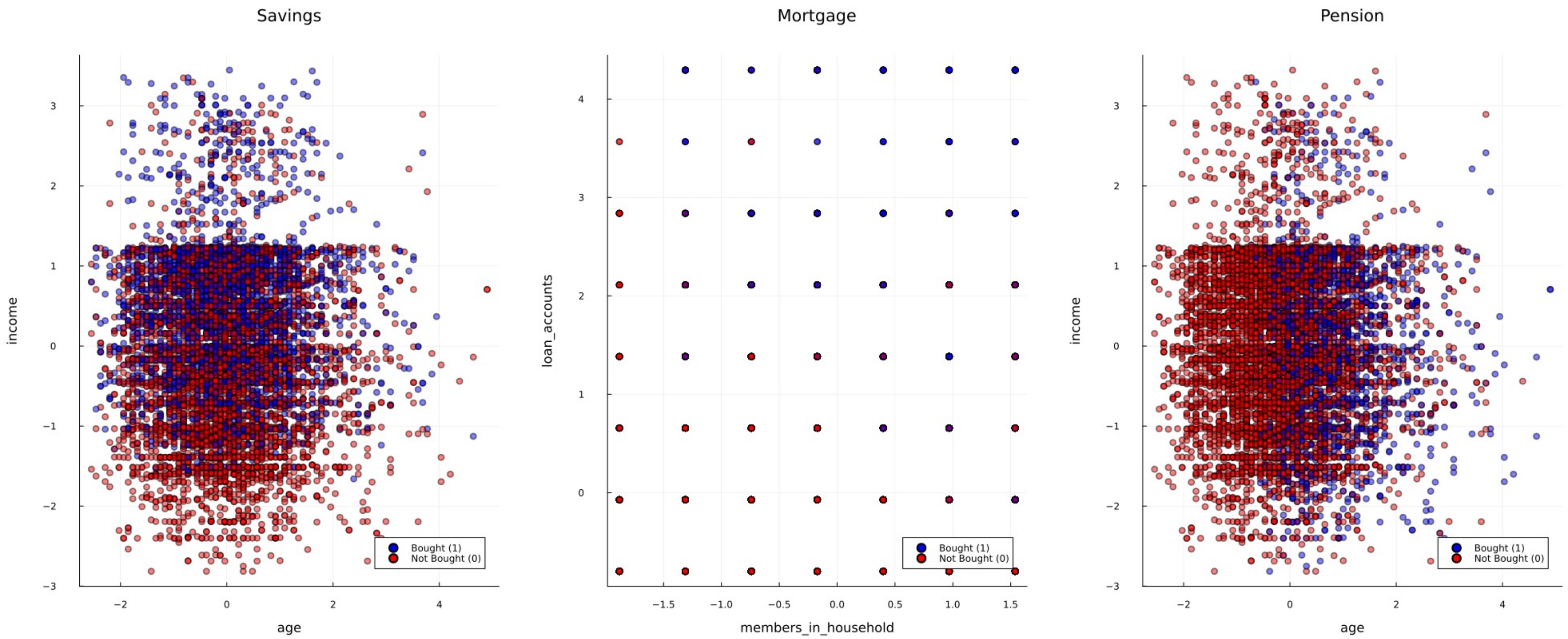
- Contact which **customers**?
- Promote which **product**?
- Through which **channel**?

EDA & FEATURE ENGINEERING



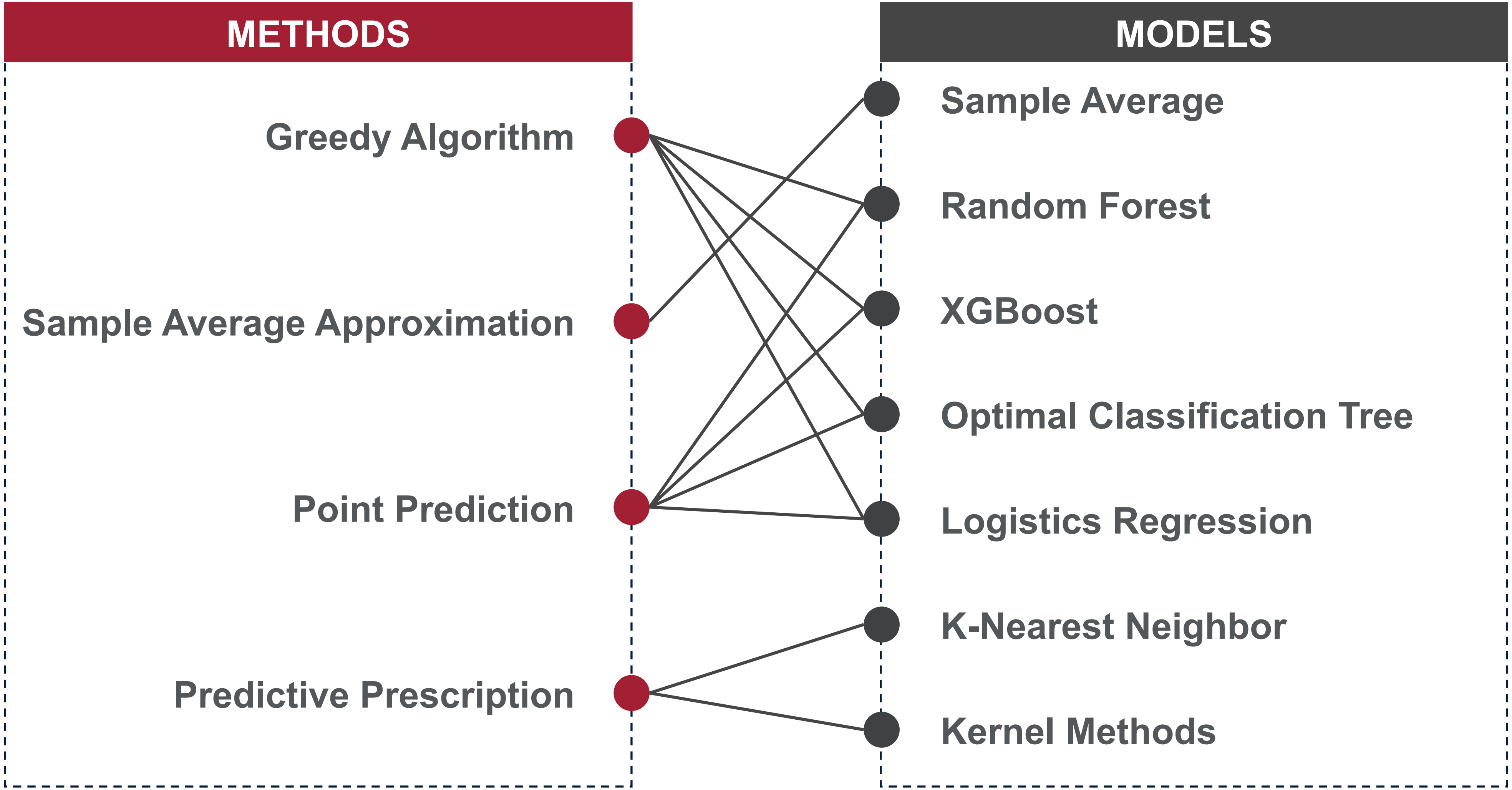
- Moderate correlation with target variables overall
- **Savings account**:
  - Income (0.2987)
- **Pension account**:
  - Age (0.3814)
  - Age of Youngest Child (0.3814)
  - Debt-to-Equity Ratio (0.3814)
  - All correlated with each other
- **Mortgage account**:
  - # Loan accounts (0.5916)
  - # Household members (0.2278)

EDA & FEATURE ENGINEERING



Selected Features: **Age, Income, Number of members in household, Number of loan accounts**

METHODOLOGY & PREDICTION MODELS



GREEDY METHOD | SERVE AS BASELINE

Greedy Algorithm (simplified pseudo code)

```
for customers from 1 to I:
    for products from 1 to J:
        for channels from 1 to K:
            if (predicted) demand is not satisfied:
                make an assignment!
```

OPTIMIZATION METHOD | E.G. PRESCRIPTIVE

Minimize minus expected profit

$$\min \sum_{i'=1}^{I_0} \sum_{i=1}^{I_1} \sum_{j=1}^{J} \sum_{k=1}^{K} w_{I_0}^{i'}(x_i) \cdot (c_k - p_j \cdot s_k) \cdot y_{i'j} \cdot z_{ijk}$$

Budget Constraint

$$\text{s.t.} \quad \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} c_k \cdot z_{ijk} \leq B$$

Minimum promotion per channel constraint

$$\sum_{i=1}^{I} \sum_{j=1}^{J} z_{ijk} \geq 0.1 \cdot I, \quad \forall k$$

At most one channel per customer

$$\sum_{k=1}^{K} z_{ijk} \leq 1, \quad \forall i, j$$

At most one product per customer

$$\sum_{j=1}^{J} z_{ijk} \leq 1, \quad \forall i, k$$

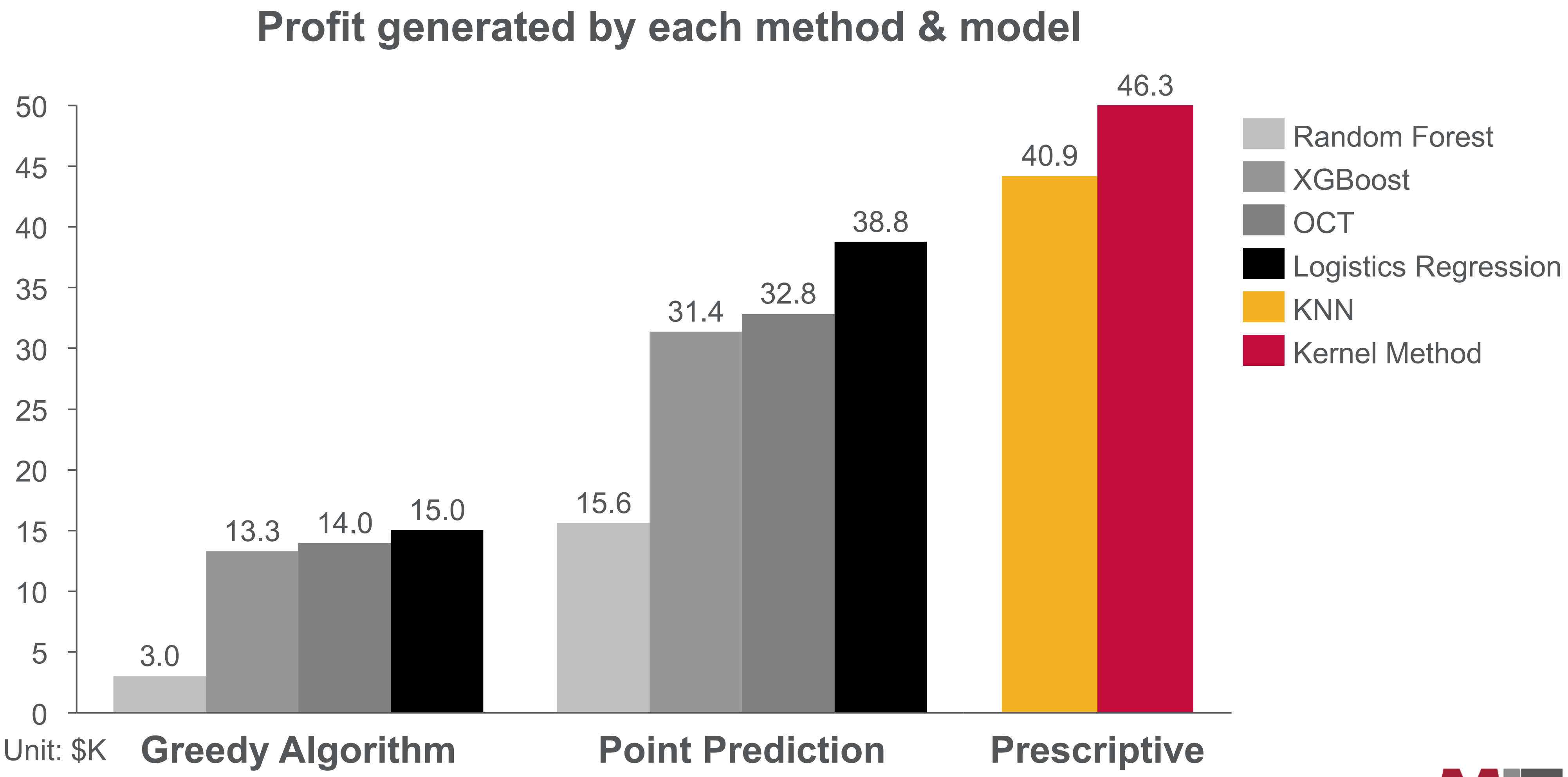
WEIGHTING MODEL | E.G. KERNEL METHODS

- **To Estimate:** $m(x) = \mathbb{E}[Y|X = x]$

$$\hat{m}_{I_0}(x) = \frac{\sum_{i'=1}^{I_0} y^{i'} K((x^{i'} - x_i)/h_{I_0})}{\sum_{i'=1}^{I_0} K((x^{i'} - x_i)/h_{I_0})}$$

- **Kernel** $K : \mathbb{R}^d \to \mathbb{R}$
- **Bandwidth** $h_{I_0} > 0$
- **Naive Kernel** $K(x) = \mathbb{I}[\|x\| \leq 1]$

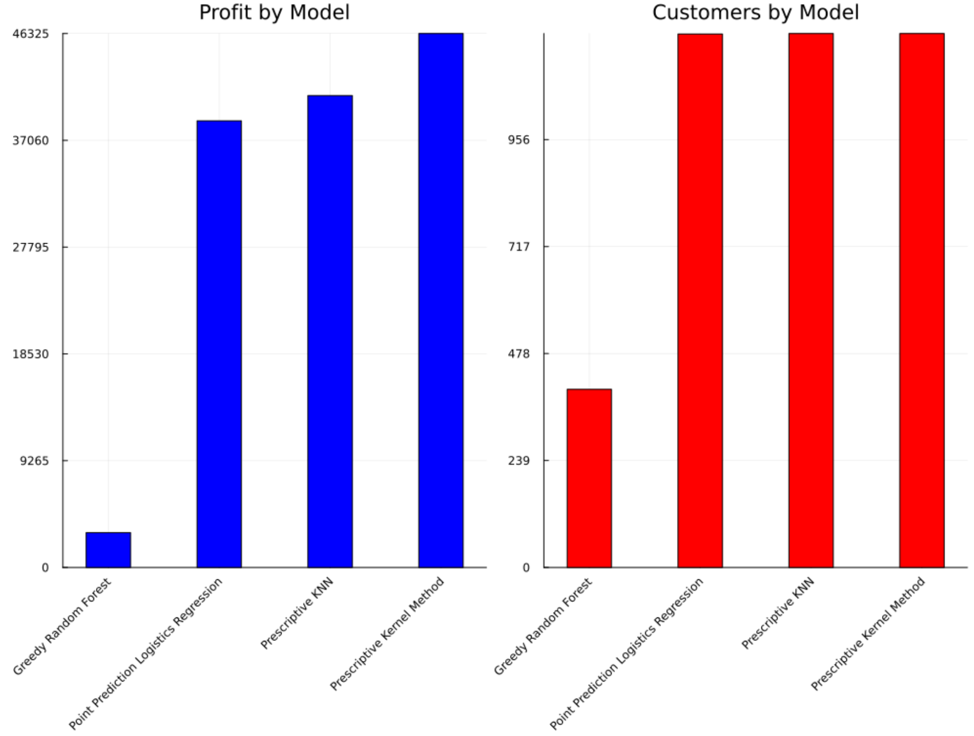
RESULT | BEST MODEL: PREDICTIVE PRESCRIPTION POWERED BY KERNEL METHODS



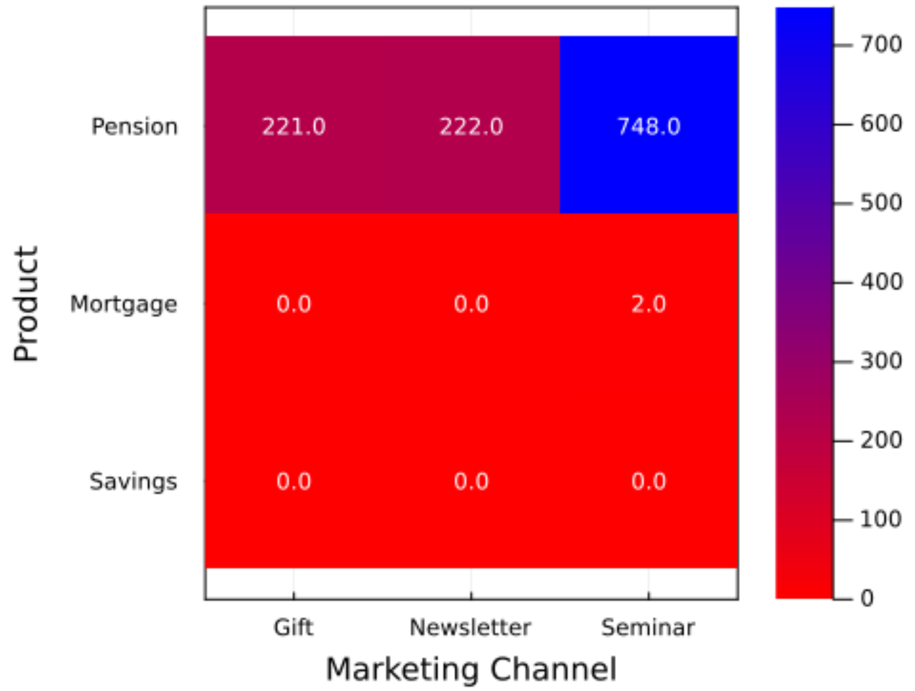
MANAGEMENT SLOAN SCHOOL

RESULT | METRIC ANALYSIS

Comparison of Profitability and Offering Ability

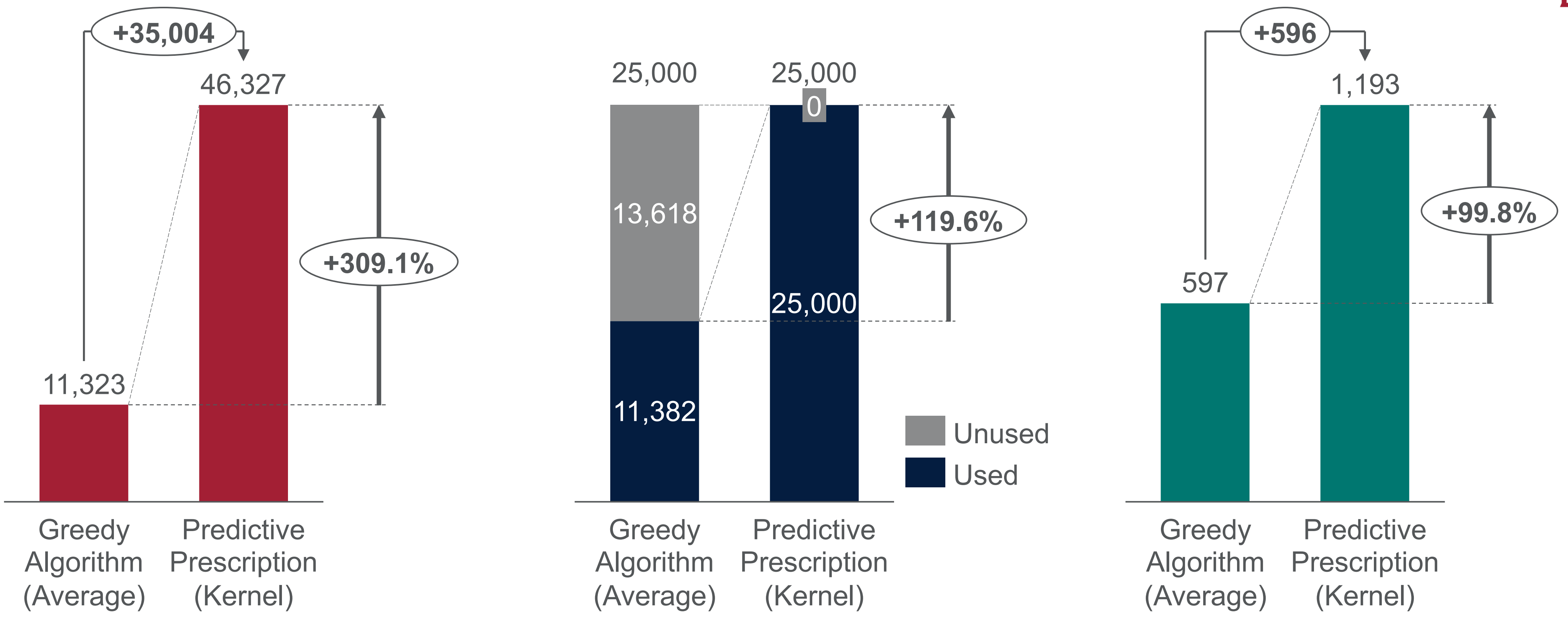


Product Offering Channels (Prescriptive Kernel Method)



- ➢ Better models serve more customers
- ➢ Best model prioritizes profitable products/channels

BUSINESS IMPACT | SIGNIFICANT IMPROVEMENT



$ Profit Generated
X 3

$ Budget Utilized
X 2

Customers Served
X 2

MIT MANAGEMENT SLOAN SCHOOL

THANK YOU!

MIT MANAGEMENT
SLOAN SCHOOL

REFERENCES

- [1] Bertsimas, Dimitris, and Jack Dunn. "Optimal classification trees." Machine Learning 106 (2017): 1039-1082.
- [2] Bertsimas, Dimitris, and Nathan Kallus. "From predictive to prescriptive analytics." Management Science 66.3 (2020): 1025-1044.
- [3] Bertsimas, Dimitris, and Nihal Koduri. "Data-driven optimization: A reproducing kernel Hilbert space approach." Operations Research 70.1 (2022): 454-471.
- [4] Bertsimas, Dimitris, and Kimberly Villalobos Carballo. "Multistage Stochastic Optimization via Kernels." arXiv preprint arXiv:2303.06515 (2023).

APPENDIX 1 | OBJECTIVE FUNCTIONS

- Sample Average Approximation

$$\hat{z}^{SAA} \in \arg\min_{z \in Z} \frac{1}{I_0} \sum_{i=1}^{I_0} \sum_{j=1}^{J} \sum_{k=1}^{K} (c_k - p_j \cdot s_k) \cdot y_{ij} \cdot z_{jk}$$

- Point-Prediction

$$\hat{z}^{point-pred} \in \arg\min_{z \in Z} \sum_{i=1}^{I_1} \sum_{j=1}^{J} \sum_{k=1}^{K} (c_k - p_j \cdot s_k) \cdot \hat{y}_{ij} \cdot z_{ijk}$$

- Predictive Prescription

$$\hat{z}_{I_0}(x) \in \arg\min_{z \in Z} \sum_{i'=1}^{I_0} \sum_{i=1}^{I_1} \sum_{j=1}^{J} \sum_{k=1}^{K} w_{I_0}^{i'}(x_i) \cdot (c_k - p_j \cdot s_k) \cdot y_{i'j} \cdot z_{ijk}$$

APPENDIX 2 | DATA STRUCTURE

Table 1: Dataset Structure and Explanation of Features

Column Name	Explanation
customer_id	id of the customer
age	age of customer
age_youngest_child	age of the customer's youngest child
debt_equity	debt to equity ratio of customer ($\times$ 100)
gender	binary variable, male-0 ,female-1
bad_payment	binary variable, whether customer has bad payment history
gold_card	binary variable, whether customer is a gold card user
pension_plan	binary variable, whether customer has a pension plan
household_debt_to_equity_ratio	household debt to equity ratio ($\times$ 100)
income	annual income of the customer ($)
members_in_household	number of members in the customer's household
months_current_account	number of months passed since the customer opened their account
months_customer	number of months passed since customer registered with the bank
call_center_contacts	amount of time spent in contact with call center
loan_accounts	number of loan accounts the customer has
number_products	number of products (except for those to be promoted) bought
number_transactions	number of transactions the customer has made
non_worker_percentage	percentage of non-workers in the customer's household
white_collar_percentage	percentage of white-collar workers in the customer's household
rfm_score	Recency, Frequency, and Monetary (RFM) score of the customer
***Mortgage**	whether the customer has opened Mortgage account (only in old customer dataset)
***Pension**	whether the customer has opened Pension account (only in old customer dataset)
***Savings**	whether the customer has opened Savings account (only in old customer dataset)

MIT MANAGEMENT SLOAN SCHOOL

APPENDIX 3 | MODEL BASIC EVALUATION

Table 2: Basic evaluation of each model

Method	Model	Revenue	Budget	Profit	Customers
Greedy	Random Forest	$7,525	$7,075	$3,025	398
Greedy	Logistics Regression	$22,660	$12,818	$15,026	663
Greedy	OCT	$21,595	$12,818	$13,952	663
Greedy	XGBoost	$20,820	$12,818	$13,291	663
SAA	Sample Average	$0	$0	$0	0
Point Prediction	Random Forest	$23,670	$16,889	$15,608	840
Point Prediction	Logistics Regression	$52,130	$24,985	$38,752	1,192
Point Prediction	OCT	$45,200	$24,985	$32,836	1,192
Point Prediction	XGBoost	$43,095	$24,295	$31,374	1,162
Prescriptive	KNN	$52,840	$25,000	$40,946	1,193
Prescriptive	Kernel Method	$59,090	$25,000	$46,327	1,193

APPENDIX 4 | PRODUCTS OFFER RESULTS

Table 3: Products offered under each model

Method	Model	Savings	Mortgage	Pension
Greedy	Random Forest	335	10	53
Greedy	Logistics Regression	206	112	345
Greedy	OCT	289	100	274
Greedy	XGBoost	320	6	337
SAA	Sample Average	0	0	0
Point Prediction	Random Forest	436	121	283
Point Prediction	Logistics Regression	308	219	665
Point Prediction	OCT	451	210	531
Point Prediction	XGBoost	501	78	583
Prescriptive	KNN	0	65	1,128
Prescriptive	Kernel Method	0	2	1,191

APPENDIX 5 | CHANNELS USED RESULTS

Table 4: Channels used under each model

Method	Model	Gift	Newsletter	Seminar
Greedy	Random Forest	221	177	0
Greedy	Logistics Regression	221	221	221
Greedy	OCT	221	221	221
Greedy	XGBoost	221	221	221
SAA	Sample Average	0	0	0
Point Prediction	Random Forest	221	221	398
Point Prediction	Logistics Regression	221	221	750
Point Prediction	OCT	221	221	750
Point Prediction	XGBoost	221	221	720
Prescriptive	KNN	221	222	750
Prescriptive	Kernel Method	221	222	750