A Structural Model of Salesforce Compensation Dynamics

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Introduction

- Compensation is a fundamental driver of productive activity
- The literature on compensation spans all aspects of business including accounting, finance, strategy, HR, operations, organizational behavior and even *marketing*.
- The fundamental question has always been to ask how might we best compensate agents to maximize output.

Introduction

- There is a long and storied literature on compensation in each of these areas.
- The fundamental building blocks are however essentially the same...

$$\textit{Effort} \rightarrow \textit{Output} \rightarrow \textit{Compensation}$$

- The idea is then to design compensation so that it maximizes the incentives for effort provision.

- Personal selling via salesforce important component of economy
  - US economy spent \$800 billion on salesforces, $\sim 3\times$ amount spent on advertising, up-to 40% of sales
  - 12% of workforce (Zoltners et al. 2008)
  - Dominant form of marketing in B2B channels
- Salesforce management relates to understanding and improving the interplay between three key actors.

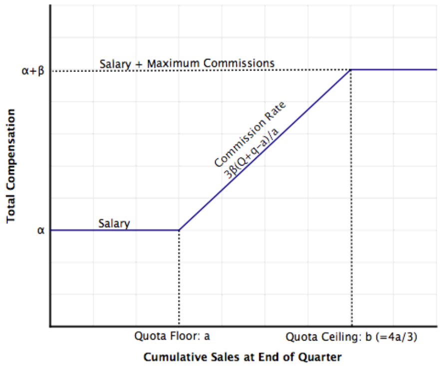
- (My own) Definition of structure:
  - Structure = Theory + Data
- Patterns in the data should be explained via models of agent behavior
  - i.e. we need micro-foundations for aggregate, macro patterns (Lucas)
- The basic idea is to use structural methods to investigate salesforce management issues.
- In essence, this brings together the two facets of of the saleforce literature...
  - Lodish, Zoltners, Weinberg, Mantrala, ...
  - Farley, Srinivasan, Lal, Coughlan, Rao, ...

Agenda

- Introduction
- Model Framework
- Data and Model-Free Evidence
- Econometric Implementation
- Results
- Implementing a New Plan
- Conclusions

Model Framework

Compensation Scheme in Data



- Compensation = Salary + Commission × **I**(Quota<Sales<Ceiling)
  - No bonus, Ceiling is a fixed fraction of quota
  - Quota is reset quarterly and is adjusted based on past

- Compensation Scheme

$$W_t = \alpha + \beta \mathbf{I}\left(I_t = N\right) \left[\begin{array}{c} \left(\frac{Q_t + q_t - a_t}{b_t - a_t}\right) \mathbf{I}\left(a_t \leq Q_t + q_t \leq b_t\right) \\ + \mathbf{I}\left(Q_t + q_t > b_t\right) \end{array} \right]$$

- States
  - Q_t, cumulative sales achieved in quarter
  - a_t, current quota
  - I_t, months since the beginning of the quarter

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- Sales are a stochastic function of effort, which is a function of the agent's state

$$q_t = g\left(e_t\left(\mathbf{s}_t\right), z\right) + \varepsilon_t$$

- Compensation Scheme

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$$q_t = g\left(e_t\left(\mathbf{s}_t\right), z\right) + \varepsilon_t$$

- Current Payoff

$$u_t = \left[\begin{array}{ccc} E\left[W_t\right] - r\,\mathrm{var}\left[W_t\right] - C\left(e_t; d\right) & \text{if} & \chi_t = 1 \\ 0 & \text{if} & \chi_t = 0 \end{array}\right]$$

Model Framework

State Transitions

- Cumulative Sales

$$Q_{t+1} = \begin{cases} Q_t + q_t & \text{if} \quad I_t < N \\ 0 & \text{if} \quad I_t = N \end{cases}$$

Model Framework

State Transitions

- Cumulative Sales

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- Quotas ("ratcheting")

$$a_{t+1} = \begin{cases} a_t & \mathit{if} \quad I_t < N \\ \sum_{k=1}^{K} \theta_k \Gamma\left(a_t, Q_t + q_t\right) + v_{t+1} & \mathit{if} \quad I_t = N \end{cases}$$

Model Framework

State Transitions

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- Months of the quarter

$$I_{t+1} = \begin{cases} I_t + 1 & \text{if} \quad I_t < N \\ 1 & \text{if} \quad I_t = N \end{cases}$$

Value Function

Early in the quota cycle

$$V\left(Q_t, a_t, N, \chi_t\right) =$$

$$\max_{\chi_{t+1},,e} \left\{ \begin{array}{l} u\left(Q_t, a_t, I_t, \chi_t, e\right) + \\ \rho \int_{\varepsilon} V\left(Q_{t+1} = Q\left(Q_t, q\left(\varepsilon_t, e\right)\right), a_{t+1} = a_t, I_t + 1, \chi_{t+1}\right) \\ \qquad\qquad\qquad\qquad\qquad\qquad \times\ f\left(\varepsilon_t\right) d\varepsilon_t \end{array} \right\}$$

Value Function

End of the quota cycle

$$V\left(Q_t, a_t, N, \chi_t\right) =$$

$$\max_{\chi_{t+1}, e} \left\{ \begin{array}{c} u\left(Q_t, a_t, N, \chi_t, e\right) + \\ +\rho \int_v \int_\varepsilon V\left(Q_{t+1} = 0, a_{t+1} = a\left(Q_t, q\left(\varepsilon_t, e\right), a_t, v_{t+1}\right), 1, \chi_{t+1}\right) \\ \times\ f\left(\varepsilon_t\right) \phi\left(v_{t+1}\right) d\varepsilon_t dv_{t+1} \end{array} \right.$$

- Optimal effort solves

$$e\left(\mathbf{s}_t; \Omega, \Psi\right) = \arg\max_{e>0} \left\{ V\left(\mathbf{s}_t; \Omega, \Psi\right) \right\}$$

- Empirical Approach
  - Estimate $\widehat{\Omega}$ given Ψ and current DGP
  - Simulate $e\left(\mathbf{s}_t; \widehat{\Omega}, \Psi = \Psi_{new}\right)$ under counterfactual

Our Data are Unusually Rich

Cross-sectional and Temporal Variation for Each Agent

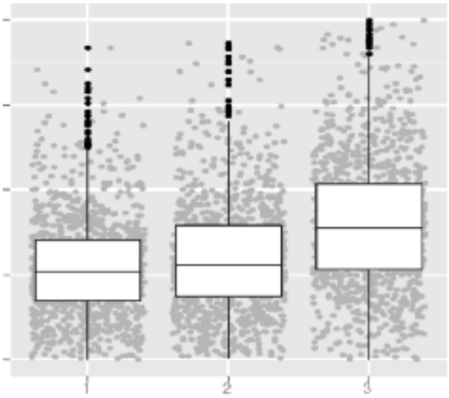
- Data come from a salesforce/division of a Fortune 500 firm
- Sales of contact lens prescribed by physician
- Spans 38 months (2005-2008)
- Sales for each salesperson at month/client level
  - Salesforce has 87 salespeople
  - on average ~160 clients per salesperson!
  - Gives us ~6080 obs **per salesperson** and ~528,960 obs total
- Complete compensation details for each salesperson
  - Quotas for each quarter
  - Commissions and salaries paid

Descriptive Statistics of Data

Variable	Mean	SD
Salary	\$67,632	\$8,585
Incentive Proportion at Quota	0.23	0.02
Age	43.23	10.03
Tenure	9.08	8.42
Num_Clients	162.20	19.09
Quota	\$397,020	\$95,680
Cum:Sales (end of quarter)	\$374,755	\$89,947
%ΔQuota (when +)	10.01%	12.48%
%ΔQuota (when -)	-5.53%	10.15%
Monthly Sales	\$138,149	\$38,319
Cum:Sales (beg: of month)	\$114,344	\$98,594
Distance to Quota (beg: of month)	\$278,858	\$121,594

Effort Timing by Agents

Model free evidence - Sales within the quarter



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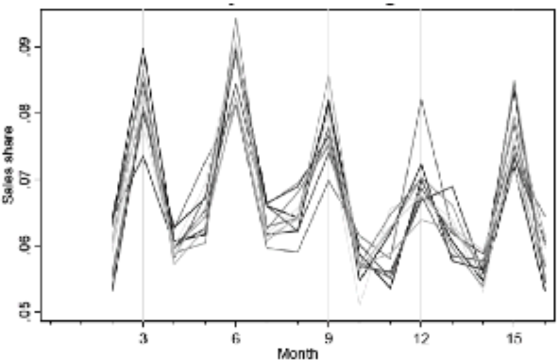
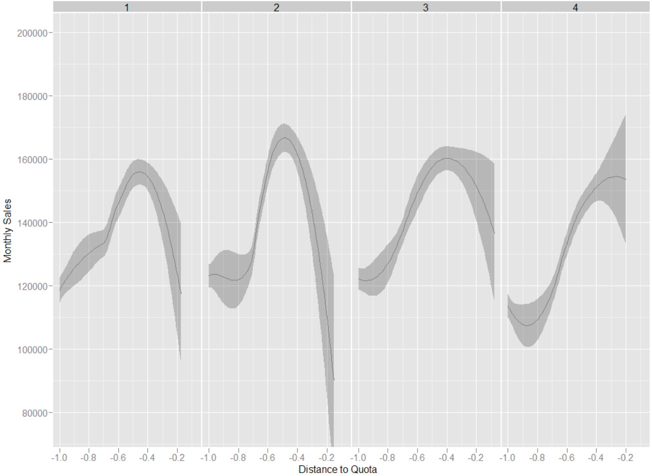


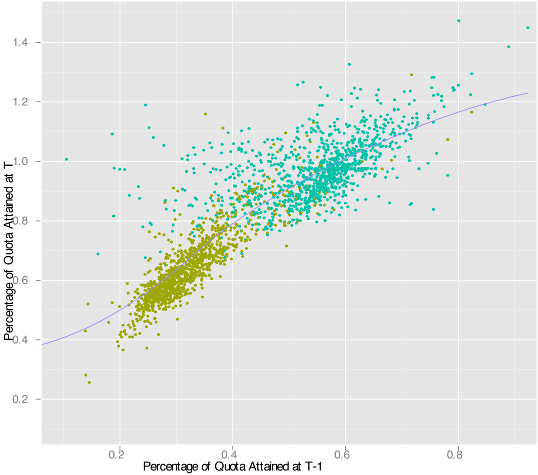
Effort Timing by Agents

Model free evidence - Sales as a function of distance to quota



Effort Timing by Agents

Model Free Evidence - Near Quota Effort



Effort Timing by Agents

Model Free Evidence - Individual Salespeople

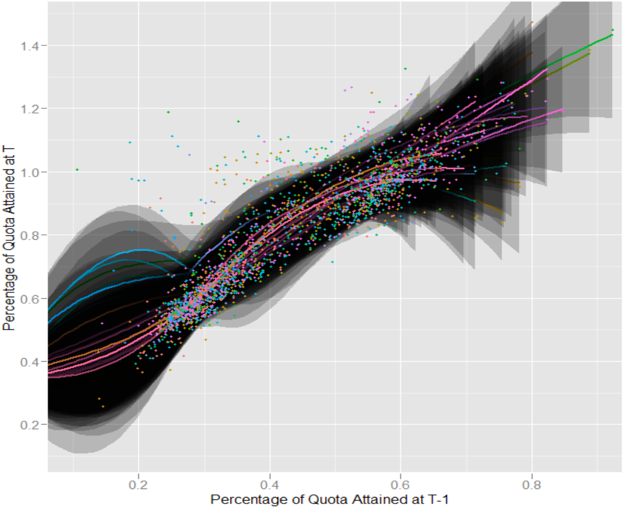
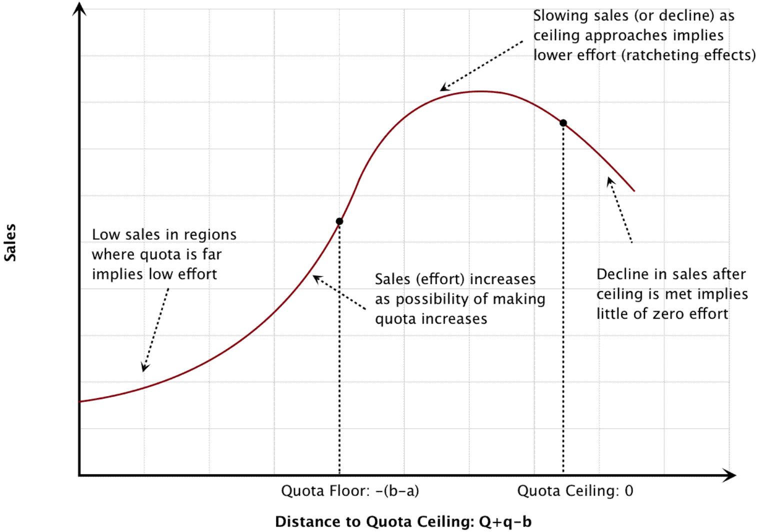


Figure:

Identification of Effort Policy



Ruling out alternative explanations

Seasonality and buyer stockpiling

- The identification of effort relies critically on mapping patterns in sales to state variables
  - We need to rule out alternate explanations for the patterns in sales
- No underlying seasonality in product demand from consumers
  - Underlying demand is generated by health outcomes
  - Consumers (or physicians) have no particular reasons to delay or accelerate demand
- Physician stockpiling limited due to profusion of products (15,000 SKU-s in product line)
  - Demand cannot be stored
  - No systematic pattern of sales being lower after months of high demand (at physician level)
  - Data based evidence in paper
- Finally, sales under new plan (with constant incentives) are flat

Econometric Implementation

Estimation Approach Details

- Our estimation approach uses a two-step approach (Bajari, Benkard and Levin 2007)
  - Non-parametrically estimate policy functions in first-stage
  - Estimate parameters by minimizing violations of dynamic optimality
- Agent-level data of unusually long duration and cross-section
  - Accommodate non-parametrically, unobserved agent heterogeneity
- Estimate policy functions & parameters agent by agent
- Important Econometric Challenge
  - Unobservability of effort (pervasive in principal-agent settings)

Econometric Implementation

Nonparametric Estimation of the Effort Policy Function

- Index clients by j
- Recall that the sales production function is

$$q_{jt} = h_j\left(z_j\right) + e\left(\mathbf{s}_t\right) + \varepsilon_{jt}$$

and z_j are time invariant client characteristics

- Project effort policy on flexible orthogonal polynomial basis functions of state variables, $\boldsymbol{\vartheta}\left(\mathbf{s}_t\right)$,

$$q_{jt} = \delta' \mathbf{z}_j + \lambda' \boldsymbol{\vartheta}\left(\mathbf{s}_t\right) + \varepsilon_{jt}$$

- Non-Linear Least Squares estimation provides, for **each** agent,
  - Effort policy function, $\hat{e}_t = \hat{\lambda}' \boldsymbol{\vartheta}\left(\mathbf{s}_t\right)$, and,
  - Empirical distribution of month-specific errors, $\hat{\varepsilon}_t = \sum_j \left(q_{jt} - \left(\hat{\delta}' \mathbf{z}_j + \hat{e}\left(\mathbf{s}_t\right)\right)\right)$

Intuition for Identification of Effort

Two steps

- Step 1: Estimate period specific productivity of sales-calls

$$q_{jt} = \delta' \mathbf{z}_j + \gamma_t + \varepsilon_{jt}$$

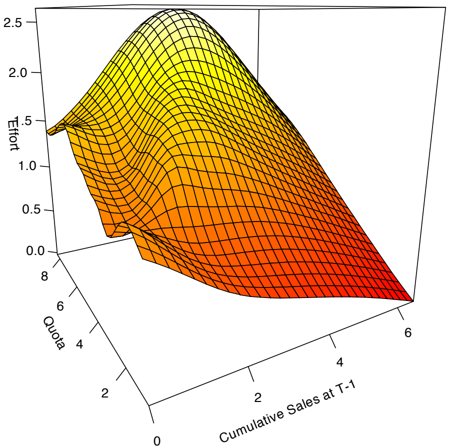
- Step 2: Project productivity on flexible function of the state

$$\widehat{\gamma}_t = \lambda' \boldsymbol{\vartheta} \left(\mathbf{s}_t \right)$$

- Identification restrictions
  - Effort is not client (j) specific
  - Optimal effort policy is a deterministic function of the observed state variables

Estimation Results

Estimated Effort Policy



Estimation Results

Examples of Individual Effort Policy Estimates

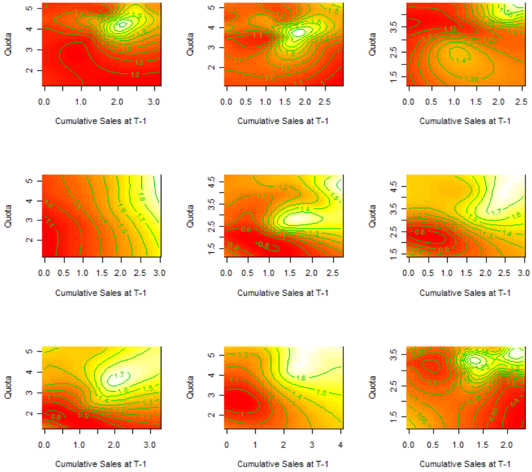


Figure:

Estimation of risk aversion and cost of effort

Minimize violations of agent optimality

Let s_0 be an initial state for an agent, (r^*, d^*) be the true parameters, and e^* the optimal effort policy at the true parameters. Then, (r^*, d^*) must satisfy,

1. Individual Rationality (IR): $V(s_0; e^*, r^*, d^*) \geq 0$
2. Incentive Compatibility (IC): $V(s_0; e^*, r^*, d^*) \geq V(s_0; e', r^*, d^*)$

Estimate (r, d) by minimizing violations of IR and IC

Let $e'(s) = e^*(s) + \varepsilon$.

Then can compute $V(s_0; e^*, \theta) = E_{e^*|s_0} \sum_{t=0}^{\infty} \beta^t E_\varepsilon [W(s, e^*(s))]$ and $V(s_0; e', \theta)$.

Estimation

- Define the following two moment conditions

$$\begin{aligned} g_1(s_0;\theta) &= \min\left(V(s_0;e^*,\theta),0\right) \\ g_2\left(s_0,e';\theta\right) &= \min\left(V(s_0;e^*,\theta) - V\left(s_0;e',\theta\right),0\right) \end{aligned}$$

and $g(s_0,e';\theta) = [g_1 \ g_2]'$

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\end{aligned}
$$

  and $g(s_0,e';\theta)=[g_1\ g_2]'$

- Define an objective function

$$
Q(\theta)=\int\left[g\left(s_0,e';\theta\right)\right]'\Lambda\left[g\left(s_0,e';\theta\right)\right]dH\left(s_0,e'\right)
$$

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$$Q (\theta) = \int \left[g \left(s_0, e'; \theta\right)\right]' \Lambda \left[g \left(s_0, e'; \theta\right)\right] dH \left(s_0, e'\right)$$

- True parameter vector $(\theta = \theta^*)$ must satisfy

$$Q (\theta^*) = \min_{\theta} (Q (\theta)) = 0$$

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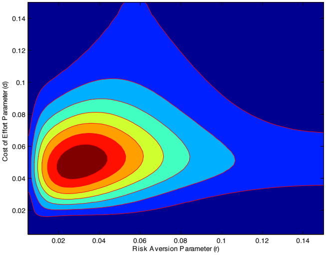
- True parameter vector $(\theta=\theta^*)$ must satisfy

$$Q(\theta^*)=\min_{\theta}\left(Q(\theta)\right)=0$$

- Solve for (r,d) agent by agent

Parameter Estimates



- Mean monthly average risk premium $\left(\mathcal{E}_{\text{agents}}\left[\frac{r}{T}\mathbb{V}\left(W\right)\right]\right) \approx$ \$340
- Mean monthly average cost of effort $\left(\mathcal{E}_{\text{agents}}\left[\frac{1}{T}d\mathbb{C}\left(e\right)\right]\right) \approx$ \$1500
- Compare to monthly (max) payout of $\approx \$7,250$

Evaluating the compensation scheme

Comparisons with counterfactual schemes

- For a given compensation plan $\wp(q(e))$ the firms discounted payoffs are

$$\widehat{\Pi}_{\wp} = \frac{1}{T \times NS} \sum_{s=1}^{NS} \sum_{\tau=0}^{T} \beta^{\tau} \left[q\left(e_{\wp}; \Psi^{s}\right) - \wp\left(q\left(e_{\wp}\right); \Psi^{s}\right) \right]$$

  - where Ψ^s is a draw from $\mathcal{G}_{\varepsilon}(\varepsilon_{\tau}) \times \mathcal{F}(\mu, r, d)$
  - and $(e_{\wp})$ is the effort policy when faced with compensation policy $\wp(q(e))$,

$$e_{\wp} = \arg\max_{e>0} V\left(s; e \middle| \{\mu, r, d\}, \wp(.)\right)$$

- Approach will be to simulate effort and sales, under the counterfactual plans
- A comparison to current policy quantities $\{\Pi^*, q^*, e^*\}$ allows a relative evaluation

Evaluating Counterfactual Plans

Finding Profit Enhancing plans

- Evaluate aspects of plan by simulating changes to contract
- Simulations reveal profit enhancing changes
  - Elimination of Quotas (no effort shading) and Ceiling (not enough demand variance)
  - Incentive horizon reduced to one month (eliminates early shirking)
  - Linear contract (no intertemporal shifting of effort)
  - Heterogenous plans

A New Compensation Plan

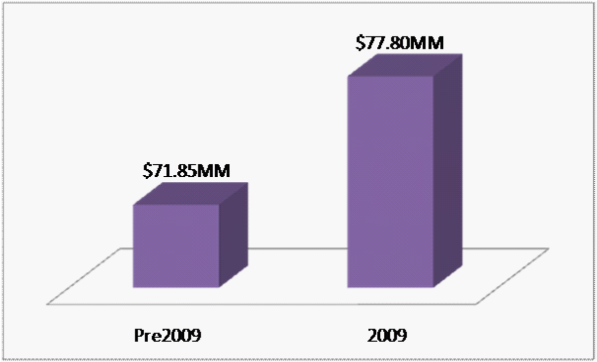
Design & Implementation

- A "Feasible" set defined by cultural, legal and infrastructural constraints at firm recommended
- Firm chose one of recommended plans
- Chosen feasible plan predicts sales would increase by about 8.6% and profits by 5.2%
- New plan introduced introduced in January, 2009
- Most changes deemed profit enhancing are incorporated (cannot reveal exact detail)
- Salespeople were informed and educated about the changes in the last quarter of 2008
- Provide evaluation using data from the first two quarters of 2009

A New Compensation Plan

Overall Results

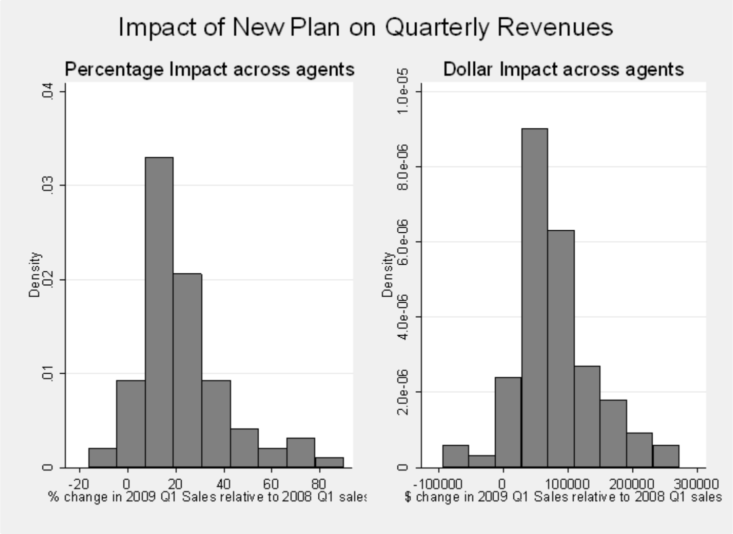
- Significant improvement in revenues!



- Year over year the increase in revenues is over 9%
- Profits (*) are also up significantly (over 6%)

A New Compensation Plan

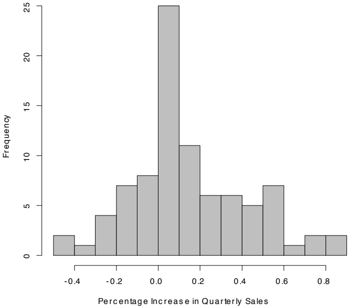
Impact Distribution across agents



A New Compensation Plan

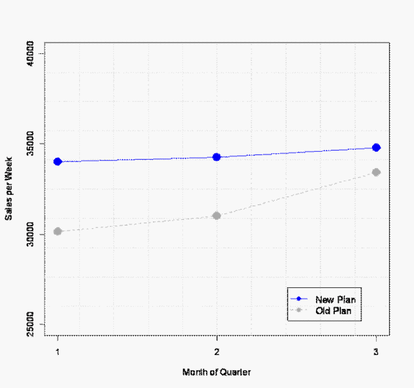
Predictions versus realized sales

- Estimated risk aversion parameter and cost of effort were significant predictors of the change in sales (p-values $= 0.0414; 0.0002$)
- Salespeople with lower cost of effort and risk aversion parameters exhibited larger improvements in sales



Validating the Model

Are changes in sales patterns as predicted?



- Significant changes in the pattern within quarter
- Sales under new plan are essentially flat!
- While all months are higher months 1 & 2 are significantly so

Conclusions

- Developed a comprehensive framework to measure the net effects of sales-force incentive schemes and evaluate counterfactual compensation plans
- Demonstrates value of using structural approaches and numerical dynamic programming based solutions to address real business problems
- Field implementation provides external validity and supports assumptions employed

Continuing Work

- Understanding composition and compensations
  - The role and scope of contract externalities
- Optimal Dynamic Contracting
  - Are real world contracts dynamically optimal?
- The Contract Economics of Startups
  - Thinking of startups as a evolution of contracts and agents