Quota Dynamics and the Intertemporal Allocation of Salesforce Effort

Sanjog Misra (Rochester Simon)  Harikesh Nair (Stanford GSB)

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Introduction
Compensation Schemes

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- Real-world compensation schemes are discrete and jumpy
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- The literature on quotas (theory and empirical) is relatively sparse
Quotas
Discontinuous changes in compensation

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- Salespeople choose effort based on achievement relative to quota
Quotas can give rise to substantial inefficiencies
Quotas and Dynamic Moral Hazard

- Quotas can give rise to substantial inefficiencies
- Effort bunching *within* a quota horizon

Goal of paper

Empirically measure effect of quota-based incentive schemes on the intertemporal allocation of effort

Extent of inefficiency (key point)

Has to be measured relative to a counterfactual compensation scheme

Requires model for simulating behavior under counterfactual

Develop dynamic structural model of agent-behavior

Agent is forward-looking, recognizes effect of current effort on future payoffs

Reducing effort has an option value
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Contribution Relative to the Literature

Rich theory, but very sparse empirical work

- Theory

- Agency theory on incentive design (Holmstrom 1979, Lazear 1986; Holmstrom & Milgrom 1987)
- Salesforce compensation & design (Basu et al. 1985; Rao 1990; Lal & Srinivasan 1993)
- Quotas (Coughlan & Narsimhan 1992; Raju & Srinivasan 1996; Gaba and Kalra 1999; Oyer 2000)
- No theory of dynamic effort allocation under quota/commission scheme (as far as we know)

Limited empirical work has focused on providing descriptive evidence that agents can manipulate timing of sales

- Healey (1985); Oyer (1998); Asch (1990); Steenburgh (2008)
- Measuring the effect of quotas on revenues
- First structural model of dynamic effort allocation in sales-force compensation setting (Larkin 2008; Copeland and Monnet 2008)

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Agenda

- Introduction
- Model Framework
- Data and Model-Free Evidence
- Econometric Implementation
- Results
- Counterfactuals
- Conclusions
Compensation Scheme in Data

- Compensation = Salary + Commission \times I(Quota < Sales < Ceiling)
  - No bonus, Ceiling is a fixed fraction of quota
  - Quota is reset on a quarterly basis and is adjusted based on current performance ("ratcheting")
Compensation Scheme

\[ w_t = \alpha + \beta I(I_t = N) \left[ \left( \frac{Q_t + q_t - a_t}{b_t - a_t} \right) I(a_t \leq Q_t + q_t \leq b_t) + I(Q_t + q_t > b_t) \right] \]
Model Framework

Compensation Scheme, States, Payoffs

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States

- \( Q_t \), cumulative sales achieved in quarter
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- **Sales are a stochastic function of effort, which is a function of the agent’s state**

  \[ q_t = g(e_t(s_t), z) + \epsilon_t \]
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Compensation Scheme, States, Payoffs

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- **Current Payoff**

\[ u_t = E [w_t] - r \text{ var} [w_t] - C \left( e_t; d \right) \]
Model Framework

Cumulative Sales

\[ Q_{t+1} = \begin{cases} 
Q_t + q_t & \text{if } I_t < N \\
0 & \text{if } I_t = N 
\end{cases} \]
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State Transitions

- Cumulative Sales

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- Quotas ("ratcheting")

\[ a_{t+1} = \begin{cases} 
a_t & \text{if } I_t < N \\
\sum_{k=1}^{K} \theta_k \Gamma (a_t, Q_t + q_t) + v_{t+1} & \text{if } I_t = N
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- **Months of the quarter**

\[
I_{t+1} = \begin{cases} 
I_t + 1 & \text{if } I_t < N \\
1 & \text{if } I_t = N 
\end{cases}
\]
Value Function

Early in the quota cycle

\[ V(Q_t, a_t, l_t; \Omega, \Psi) = \]

\[
\max_{e>0} \left\{ \begin{array}{c}
\quad u(Q_t, a_t, l_t, e; \Omega, \Psi) \\
+ \rho \int_{\varepsilon} V(Q_{t+1} = Q(Q_t, q(\varepsilon_t, e)), a_{t+1} = a_t, l_t + 1; \Omega, \Psi) \\
\times f(\varepsilon_t) d\varepsilon_t
\end{array} \right. \]
Value Function

End of the quota cycle

\[ V(Q_t, a_t, N; \Omega, \Psi) = \]

\[
\max_{e > 0} \left\{ \begin{array}{l}
\begin{align*}
u(Q_t, a_t, N, e; \Omega, \Psi) \\
+ \rho \int \int V(Q_{t+1} = 0, a_{t+1} = a(Q_t, q(\varepsilon_t, e), a_t, \nu_{t+1}), 1) \\
\times f(\varepsilon_t) \phi(\nu_{t+1}) d\varepsilon_t d\nu_{t+1}
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Value Function

End of the quota cycle

\[ V (Q_t, a_t, N; \Omega, \Psi) = \max_{e > 0} \begin{cases} u (Q_t, a_t, N, e; \Omega, \Psi) \\ + \rho \int_{v} \int_{\varepsilon} V (Q_{t+1} = 0, a_{t+1} = a (Q_t, q (\varepsilon_t, e), a_t, v_{t+1}) , 1) \times f (\varepsilon_t) \phi (v_{t+1}) \, d\varepsilon_t \, dv_{t+1} \end{cases} \]

- Optimal effort solves

\[ e (s_t; \Omega, \Psi) = \arg \max_{e > 0} \{ V (s_t; \Omega, \Psi) \} \]
Value Function

End of the quota cycle

\[ V(Q_t, a_t, N; \Omega, \Psi) = \]

\[ \max_{e > 0} \left\{ u(Q_t, a_t, N, e; \Omega, \Psi) \right. \]

\[ + \rho \int_v \int_\varepsilon V(Q_{t+1} = 0, a_{t+1} = a(Q_t, q(\varepsilon_t, e), a_t, \nu_{t+1}), 1) \]

\[ \times f(\varepsilon_t) \phi(\nu_{t+1}) \, d\varepsilon_t \, d\nu_{t+1} \]

- Optimal effort solves

\[ e(s_t; \hat{\Omega}, \Psi) = \arg \max_{e > 0} \left\{ V(s_t; \Omega, \Psi) \right\} \]

- Empirical Approach

  - Estimate \( \hat{\Omega} \) given \( \Psi \) and current DGP
  - Simulate \( e(s_t; \hat{\Omega}, \Psi = \Psi_{new}) \) 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
- Medical product (non-pharma) prescribed by physician
- Spans four years (2004-2007)
- Sales and detailing calls for each salesperson at month/client level
  - Salesforce has about 90 salespeople
  - on average ~150 clients per salesperson!
  - Gives us ~3600 obs per salesperson and ~324,000 obs total.
- Complete compensation details for each salesperson
  - Quotas for each quarter
  - Commissions and salaries paid.
### Descriptive Statistics of Data

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

% Quota at end of month 2
% Quota at end of month 3
% Quota at end of month 2
% Quota at end of month 3

Misra & Nair (Rochester & Stanford)
Quota Dynamics
February 2009
Our estimation approach uses a two-step approach (Bajari, Benkard and Levin 2007)
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- Non-parametrically estimate policy functions in first-stage estimation approach.
- Estimate parameters by minimizing violations of dynamic optimality.
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Important Econometric Challenge

Unobservability of effort (pervasive in principal-agent settings)
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Important Econometric Challenge

- Unobservability of effort (pervasive in principal-agent settings)
Identification of Effort Policy

Figure: Misra & Nair (Rochester & Stanford)
Quota Dynamics
February 2009 18 / 39

Sales

Low sales in regions where quota is far implies low effort

Sales (effort) increases as possibility of making quota increases

Slowing sales (or decline) as ceiling approaches implies lower effort (ratcheting effects)

Decline in sales after ceiling is met implies little of zero effort

Quota Floor: -(b-a)  Quota Ceiling: 0

Distance to Quota Ceiling: Q+q-b
Econometric Implementation
Nonparametric Estimation of the Effort Policy Function

- Control Variable
Control Variable

Quality of sales-calls (unobserved), $e_t$
Control Variable

- Quality of sales-calls (unobserved), $e_t$

Recall that the sales production function is

$$ q_{jt} = h_j(z_j) + e(s_t)D_{jt} + \varepsilon_{jt} $$
Control Variable

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where $D_{jt}$ is the number of calls made to client $j$ at time $t$. 

Nonparametric Estimation of the Effort Policy Function

Project effort policy on flexible orthogonal polynomial basis functions of state variables, $\vartheta (s_t)$,
Control Variable

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- where $D_{jt}$ is the number of calls made to client $j$ at time $t$
- and $z_j$ are time invariant client characteristics
Control Variable
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Project effort policy on flexible orthogonal polynomial basis functions of state variables, $\vartheta(s_t)$,

$$q_{jt} = \delta'z_j + \lambda'\vartheta(s_t)D_{jt} + \varepsilon_{jt}$$
Econometric Implementation

Nonparametric Estimation of the Effort Policy Function

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  - Quality of sales-calls (unobserved), $e_t$

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Project effort policy on flexible orthogonal polynomial basis functions of state variables, \( \vartheta (s_t) \),

\[
q_{jt} = \delta' z_j + \lambda' \vartheta (s_t) D_{jt} + \varepsilon_{jt}
\]

Non-Linear Least Squares estimation provides, for each agent,

- Effort policy function, \( \hat{e}_t = \hat{\lambda}' \vartheta (s_t) \), and,
- Empirical distribution of month-specific errors,

\[
\hat{e}_t = \sum_j \left( q_{jt} - \left( \delta' z_j + \hat{e} (s_t) D_{jt} \right) \right)
\]
Intuition for identification of effort

Two steps

- Step 1: Estimate period specific productivity of sales-calls
  \[ q_{jt} = \delta' z_j + \gamma_t D_{jt} + \varepsilon_{jt} \]

- Step 2: Project productivity on flexible function of the state
  \[ \hat{\gamma}_t = \lambda' \theta (s_t) \]
Estimation Results

Estimated Effort Policy ("average" agent)

[Diagram showing a 3D model with axes for Quota, Cumulative Sales at T-1, and Monthly Sales]
Estimation Results
Examples of Individual Effort Policy Estimates

- Cumulative Sales at T-1 vs Quota
- Cumulative Sales at T-1 vs Quota
- Cumulative Sales at T-1 vs Quota
- Cumulative Sales at T-1 vs Quota
Above quota policy was estimated using bivariate splines. (Preliminary)

For now we use,

\[ a_{t+1} = 1.25 a_t + 0.539 Q_t \]

\( R^2 = 0.48 \)
Recall that optimal effort solves

\[ e(s_t; \Omega, \Psi) = \arg\max_{e > 0} \{ V(s_t; \Omega, \Psi) \} \]

This requires solving for the fixed point in \( V \) and maximizing to obtain \( e_t \).

The optimal effort policy was solved using modified policy iteration (Rust 1996).

- Policy approximated over the two continuous states using 10 points in each state dimension.
- Expectations over the distribution of the demand shocks \((\epsilon_t)\) implemented using Monte Carlo integration using 1000 draws.
- Quota ratcheting error, \((\nu_{t+1})\) was integrated out using Gauss Hermite quadrature.
- Maximization involved in computing optimal policy was implemented using the highly efficient SNOPT solver.
Optimal Effort-Policy

Distortions from Quota

Effort Policy: Month 3

Figure:

Quota Increases Effort

State of Cumulative Sales Influences Effort

Misra & Nair (Rochester & Stanford)

Quota Dynamics

February 2009
Value Function
End of quarter value function

Value Function: Month 3

Dollars
Quota (100K)
Cumulative Sales (100K)

Quota Dynamics
February 2009
Predicted Sales from Model

Recovering the “Scalloped” Sales Patterns

Figure:

- DP recovers the sales pattern in the data “remarkably” well
- Under predicts sales in months 1 and 2 and overpredicts in 3.
Evaluating the compensation scheme
Comparisons with counterfactual schemes

- First-best (firm can observe effort)
Evaluating the compensation scheme
Comparisons with counterfactual schemes

- First-best (firm can observe effort)
  - Measure of cost of asymmetric information in the compensation scheme
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- Linear contract
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- No intertemporal reallocation under either plan
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- Linear contract
  - Optimal under “LEN” assumptions
- No intertemporal reallocation under either plan
- Approach will be to simulate effort and sales, under the two plans
Counterfactuals: Alternative Compensation Schemes
Comparing to the first best

- First best achieves quarterly sales of about $800,000
- Compared to average sales of $370,000 under the current plan
- A linear compensation plan with a 9% commission would achieve similar sales.
Conclusions

- Developed a realistic framework to understand the net effects of quota based schemes in real-world business settings.
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- Key point is that evaluation has to be based on a counterfactual
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- Continuing to evaluate other counterfactuals to better understand policy, and to generate normative predictions for the firm
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- Continuing to evaluate other counterfactuals to better understand policy, and to generate normative predictions for the firm
  - Your comments are welcome!
Thank you!
Analysis of Sales-Calls

Sales-Calls are not a decision variable for the agent

- Neither number nor allocation of calls across clients is under control of the agent.
- Management pre-specifies number and distribution of calls across client types.
- Agents adhere closely to this top-down management specification.
- Though sales-calls are observed, the firm specifies compensation based on sales, not calls.
Analysis of Sales-Calls

Agents adhere closely to specifications
Analysis of Sales-Calls

Sales-Calls do not explain sales, and are unrelated to quota attainment

Figure: Number of sales-calls and Realized Sales
Analysis of Sales-Calls

Sales-Calls Distribution across clients do not vary by month-of-the-quarter

**Figure:** Sales-Calls by Client Type
Analysis of Sales-Calls
Sales-Calls Distribution across clients do not vary by month-of-the-quarter

Figure: Proportion of calls made by month-of-quarter to type ‘A’ clients
Analysis of Sales-Calls

Sales-Calls Distribution across clients do not vary by month-of-the-quarter

Figure: Proportion of calls made by month-of-quarter to type ‘B’ clients
Analysis of Sales-Calls

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Figure: Proportion of calls made by month-of-quarter to type ‘C’ clients