The Efficiency-Quality Trade-Off of Cross-Trained Workers

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Motivation

Generalists vs. Specialists in Medicine

Labor and Delivery Story

- Why wasn't there an obstetrician on duty?
- Staffing flexible servers (i.e. generalists) is more ***efficient*** given heterogeneous customers, ***all else being equal***
- What about ***cost***?
- What about ***speed*** of service?
- What about ***quality*** of service?

Call Centers
Other fields?

Agenda

- Overview
- Model Formulation
  - Service Process Model
  - Tenure Process
  - Service Quality and the Value to the Firm of Worker Experience
- Service Process Approximation Method
- Numerical Experiments
  - General Model Testing and Insights
  - Case Study
- Conclusions
- Critique
- Questions / Discussion

Overview

Goal: Study the trade-off between the cost efficiency provided by cross-trained (or generalist) workers and the experience based quality provided by specialists

Develop a general model that integrates:

- Queuing system model that includes multiple server types
- Model of an individual worker's career path (tenure)
- Model of experience-based learning

- Output of system = Revenue (varies with the quality of service)
- System Performance = Gross Profits (varies with both revenue and costs)

Links managerial decisions about staffing policies and worker specialization with worker learning curves, system costs and service quality

Model Formulation

- **The Service Process Model**
  - Who gets served?
  - By whom?
- **Employee Tenure Model (*Tenure Process*)**
  - Experience of Servers
- **Experience-Based Learning Model of Service Quality**
  - Experience → Service Quality
  - Service Quality → Value to the Firm (Revenue)
- **Objective Function**
  - Expected Profit of the Firm

The Service Process Model

(See Figure 1 on page 34 of the Pinker and Shumsky paper)

- **Focuses on quality of service** [f(server experience)]
  - Traditional focus is on waiting time or time in system
- **Assumes that service standards** (e.g. % customers served) **are set exogenously**
  - Treated as constraints in the model
- **Models the SP structure as a "loss system"** (i.e. queuing not allowed)
  - Above routing scheme achieves the highest server utilization

The Service Process Model Statistics

Throughput:

$$R = R_{AA} + R_{BB} + R_{AF} + R_{BF}$$

(Erlang's Loss Formula , Approximation Method)

Server Utilization:

$$\rho_{AA}, \rho_{BB}, \rho_{AF}, \rho_{BF}$$

(Little's Law)

$$\rho_{AF} = R_{AF} / (\mu_F N_F)$$

Tenure Process

- ***Tenure*** defined
- Model tenure as a random variable drawn from a ***mixed exponential probability distribution***

(See Figure 2 on page 35 of the Pinker and Shumsky paper)

$\lambda_2 > \lambda_3$ $p = \lambda_1 / (\lambda_1 + \lambda_2)$

- Career path model – can be modeled as states of a continuous time Markov chain
- Time a worker stays in a given stage is exponentially distributed
- What is the ***expected length of tenure***?

Tenure Process Statistics

- x = worker tenure of a worker

$$\Pr\{x > t\} = G_x(t) = \frac{\lambda_2 - \lambda_3}{\lambda_1 + \lambda_2 - \lambda_3} e^{-(\lambda_1 + \lambda_2)t} + \frac{\lambda_1}{\lambda_1 + \lambda_2 - \lambda_3} e^{-\lambda_3 t}$$

$$E(x) = \frac{1}{\lambda_1 + \lambda_2}\left(1 + \frac{\lambda_1}{\lambda_3}\right)$$

- y = time worked

$$g_y(t) = \frac{G_x(t)}{E[x]}$$

Service Quality and the Value to the Firm of Worker Experience

How does worker experience translate into monetary value to the firm?

Worker Experience → **Service Quality** → **Firm Revenue**

Experience-based
Service Quality

$$Q(b) = Lb^{n_1}$$

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Value of Increased Quality

$$V(q) = Mq^{n_2}$$

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Experience-based Service Quality

$$Q(b) = Lb^{n_1}$$

Value of Increased Quality

$$V(q) = Mq^{n_2}$$

Revenue generated by a worker with b time units of experience in a particular task

$$W(b) = Kb^{n}$$

$$K = L^{n_2}M \quad , \quad n = n_1 n_2$$

Objective Function

Maximization of Expected Gross Profits

$$\text{Revenue} = \sum_i \sum_j R_{ij} E\left[W(b_{ij})\right]$$

Where: $\boldsymbol{i} = \boldsymbol{A}$ or $\boldsymbol{B}$
$\boldsymbol{j} = \boldsymbol{A}, \boldsymbol{B}$ or $\boldsymbol{F}$

Labor Only

$$\text{Cost} = c_A N_A + c_B N_B + c_F N_F$$

Expected Profit of the firm: $Z = \text{Revenue} - \text{Cost}$

Approximating the Average Quality

Link the models for tenure, learning and service

$$E\left[W(b_{ij})\right] = K_{ij} E_y \left[E\left[b_{ij}^n \middle| y\right]\right]$$

conditioning the probability distribution of b_{ij} on y

$$E\left[W(b_{ij})\right] \approx \int_0^\infty K_{ij} (\rho_{ij} t)^n g_y(t) dt$$

$$= \frac{\lambda_3(\lambda_1+\lambda_2) K_{ij} \Gamma(n+1) \rho_{ij}^n}{(\lambda_2-\lambda_3)\lambda_3 + \lambda_1(\lambda_1+\lambda_2)} \bullet \left\{ \frac{(\lambda_2-\lambda_3)}{(\lambda_1+\lambda_2)^{n+1}} + \frac{\lambda_1}{\lambda_3^{n+1}} \right\}$$

Approximation Error

$$\varepsilon(\mathrm{Y}) = \frac{\left[E\left[b_{ij}^{n} \middle| \mathrm{Y}\right]\right] - (\rho_{ij}\mathrm{Y})^{n}}{(\rho_{ij}\mathrm{Y})^{n}} = E\left[\left(\frac{b_{ij}}{\rho_{ij}\mathrm{Y}}\right)^{n} \middle| \mathrm{Y}\right] - 1$$

Lemma 1:

$$\lim_{Y \to \infty} E\left[\left(\frac{b}{\rho \mathrm{Y}}\right)^{n} \middle| \mathrm{Y}\right] = 1$$

Implies: $\lim_{Y \to \infty} \varepsilon(\mathrm{Y}) = 0$

How long does it take for the true expectation and the approximation to converge?

(i.e. *How long does a server have to be on the job for the approximation to be close enough?*)

Simulation Results

(See Figure 3 on page 39 of the Pinker and Shumsky paper)

Impact of Staff Mix on ***Cost***

(See Figure 4 on page 41
of the Pinker and Shumsky paper)

Cost / Customer:

$$\frac{c_A N_A + c_B N_B + c_F N_F}{\lambda_A + \lambda_B}$$

Impact of Staff Mix on *Quality*

(See Figure 5 on page 41
of the Pinker and Shumsky paper)

Quality / Customer:

$$\frac{\sum_i \sum_j R_{ij} E\left[W(b_{ij})\right]}{\lambda_A + \lambda_B}$$

What is the *Right* Staff Mix?

- **Trade-off between efficiency and quality**
- **Only generalists, only specialists, or *OPTIMAL mix***

(See Table 1 on page 42
of the Pinker and Shumsky paper)

- **Suggests that there is an optimal mix**
- ***When is it important to determine the optimal mix?***

When is the Optimal Staff Mix Important?

(See Figure 6 on page 42
of the Pinker and Shumsky paper)

Which Extreme System is *Best*?

Optimal	**Specialized**
Flexible	

(This graphic can be superimposed over Figure 7
on page 43 of the Pinker and Shumsky paper)

Optimal Staffing Configurations

(See Figure 8 on page 44
of the Pinker and Shumsky paper)

System Performance - ***Profit***

(See Figure 9 on page 45
of the Pinker and Shumsky paper)

System Performance - ***Quality***

(See Table 3 on page 45
of the Pinker and Shumsky paper)

Conclusions

- ***"Flexible workers provide more throughput while using fewer workers" – from the Pinker and Shumsky paper, page 46.***
- ***(For other conclusions, see page 46 of the Pinker and Shumsky paper)***

Shortcomings / Future Work

- **Service systems in practice are substantially more complex than the system described in the paper**
- **Many service systems allow customers to *queue* for service**
  - Could extend the model to reflect the impact of waiting time on perceived service quality in the performance measure Z
- **In addition to learning, many times *forgetting* is an important phenomenon**
  - Could incorporate forgetting into the learning curve model to allow quality to drop when utilization drips below some threshhold
- **Extensions to the model to represent a more elaborate service facility:**
  - **More customer and service classes**
  - **Heterogeneous service rates and tenure processes among server classes**
- **Other uses for the Model:**
  - **Assess the benefits of training programs and IT that transfers knowledge between specialists and flexible workers**
  - **Asses personnel assignment decisions (e.g. job rotation to prevent burnout)**

Critique

- **<u>Main Contribution</u>: First work to integrate the study of service process systems, learning curves, and the modeling of turnover and career paths.**
- **Provides a fair amount of practical insight that could be useful**
  - When is it important to have the optimal mix vs. using an extreme solution
  - All-specialists seems to dominate all-flexible except in the extreme case of a small system and little learning
- **Provides a simple framework for expanding the study to include exploring other options**
- **I would like to see how the single-overflow configuration would have performed relative to the others (for quality) if optimized for Z (instead of min Cost)**
- **The paper is well written with the right amount of mathematical detail for the intended purpose**

Discussion