Managing Information Intensive Service Facilities: Executive Contracts, Market Information, and Capacity Planning

Yabing Jiang
Graduate School of Business Administration
Fordham University
yajiang@fordham.edu

Abraham Seidmann
Simon Graduate School of Business Administration
University of Rochester
seidmannav@simon.rochester.edu

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Effectively managing IT service centers such as call centers, computerized diagnostic imaging facilities, data centers, e-commerce sites, SaaS, and telecommunication networks has always been a challenging task, especially, when the managers running the centers possess private information about market condition and their marketing efforts. Prior studies often model IT service centers as queueing systems with exogenous demand and mostly focus on capacity allocation through an internal pricing scheme. Demand uncertainty and managers' private information (i.e., agency issues) are usually ignored. For service centers in general, customers often experience delays due to stochastic arrivals and random service times. Successfully soliciting market information from the managers becomes critical for the centers' profitability. If firms invest too much in capacity, while delay costs are under control capacity costs go up. If firms under-invest in capacity then delay costs explode. Because managers' information regarding market demand is valuable for the firms, how to solicit true market information and thereby induce desired levels of marketing effort from the managers becomes critical and is the focus of this paper. We develop two incentive contracts that can effectively induce true market information from the managers. We show that one contract can even induce the first-best effort levels from the managers. Our study provides guidelines for firms that deal with congestion-prone systems with incomplete information, and it sheds light on how to effectively manage service facilities with combined moral hazard and adverse selection issues.

1. Introduction and overview

Effectively managing service centers such as call centers, computerized diagnostic imaging facilities, data centers, e-commerce sites, SaaS, and telecommunication networks has always been a challenging task. Owners of the centers (firms) are responsible for capacity investment, which is often capital intensive and involves significant upfront fix costs. While high utilization is desirable to stay profitable, firms also have to maintain an acceptable service level in order to compete. Managers of these centers, on the other hand, are usually responsible for managing daily activities and generating demand through marketing. For example, at most free-standing radiology facilities such as those run by Insight Imaging, the local managers are responsible for marketing and demand generation. Because managers often run the service centers as a profit center, demand generation is a critical job function that they perform. What makes the issue complicated is that managers, as the agents running the service centers, often possess private information about market condition and their marketing efforts. Thus, firms (principals) would like to induce true market information from the managers when making capacity investment. This, however, is not an easy task because managers often have diverged interests. In this paper, we apply the principal-agent framework to address the service center capacity management and mechanism design issues.

Prior researches [3, 4, and 10] have modeled IT service centers as queueing systems and mostly focused on capacity allocation within a firm through an internal pricing scheme. In these works, demand is exogenous and there is no agency issue. Clearly, this model setting does not apply to many IT service centers that we mentioned above. Harris et al. [5] study effective resource allocation under incomplete information. This is one of the early works on mechanism design. In their model, agents have private information on their productivities and effort levels. The objective of the firm is to minimize the costs of producing a given level of output by designing an efficient mechanism which outlines how to allocate a common resource produced by one agent to other agents to product the final products. However, since the output level is given there is no demand uncertainty in their model. Hasija et al. [6] study call-center outsourcing contracts. In their model, the call-center vendor has private information on its staff's efficiency (i.e., service rate) and decides a staffing level which affects the call-center service quality. The client offers outsourcing contracts which specify financial and service quality terms. They evaluate different contract forms with the aim of finding contracts that coordinate the service supply chain, i.e., contracts that induce the vendor to choose the optimal staffing level which maximizes the total supply-chain profit. Here, the vendor makes staffing decision which affects the call-center's service quality, but it has no influence on market demand.

This paper is also related to [2] since both study a problem which combines moral hazard with adverse selection. In Chen's [2] paper, the agent (a sales agent with negative exponential utility function) has private information on market condition and exerts selling effort which is not observable by the principal. The principal makes inventory stocking decision and designs a compensation scheme (linear contract) to induce the agent to truthfully reveal market condition so that it can better match supply with demand. The focus of [2], however, is to derive the corresponding Gomik's scheme and compare it with a menu of linear contracts. We instead focus on service center incentive contract design in this paper. Similarly, the agent has private information on market demand and can increase demand by investing in marketing effort. The principal makes capacity investment and designs a menu of contracts. But here, because of demand uncertainty and the stochastic arrival and service processes, customers often experience delays at the service center, and customer delays cannot be resolved by overstocking inventory but by investment in capacity or staffing. If the principal invests too much in capacity, while the delay costs are under control capacity costs go up. If the principal under-invests in capacity then delay costs explode. Thus, the principal would like to induce market information from the agent in order to determine the optimal capacity level. We develop two incentive contracts, both of which can induce true market information from the manager. And one even induces the first-best effort level from the agent.

Our study also extends Basu et al. [1], who focus on the compensation contract design of a sales force selling a commodity good with an unlimited supply. In contrast, we and [8] model the capacity management and contract design issue of a service organization with a finite capacity. And we extend [8] by allowing the agent to possess private information regarding market demand and including mechanism design in the model. Our study provides guidelines for firms that deal with congestion-prone systems and sheds light on how to effectively manage service facilities with combined moral hazard and adverse selection issues.

2. The model

Consider a service center such as a data center or an application service provider with a random demand. There is one principal—the owner of the center and one agent—the manager of the center. The owner is responsible for capacity investment and the manager is responsible for managing the center and marketing its service. We model the service center as an M/M/1 queueing system, where the arrivals of service requests are independent and follow a Poisson process with a rate of λ requests per unit time, and the service time has an exponential distribution with service rate μ.

Let r be the revenue from processing a service request. We assume that the marginal cost of processing a request is constant, and it is normalized to zero. Because of demand uncertainty and the stochastic arrivals of service requests as well as random service time, the service center often experience queueing delays. Let W be the expected time in the system for a service request. That is W includes waiting time in queue and service time. In order to compete in the market, the service center has to meet a service standard: $W \leq W_0$, which means that the center promises to its clients that a service request's expected time in the system is no longer than W_0. We can think of W_0 as an industry-wide service standard. Let c be the per unit capacity cost, assuming linear capacity cost function. The owner needs to make corresponding capacity investment to ensure that the center will meet the service standard.

Let θ be the expected base demand, which is the exogenous expected service demand without the manager's marketing effort. Different from [3, 4, and 10], here service demand can be influenced by the manager's marketing effort α, where $\alpha \in \mathrm{A} \subseteq R^+$. In particular, $\lambda = \theta + \phi(\alpha)$, i.e., when the manager invests in marketing effort α, the expected demand increases by $\phi(\alpha)$. We assume that $\phi(\alpha) = k\alpha$. In addition, the expected base demand θ is a random variable, which could be θ_h and θ_l ($\theta_h > \theta_l$) with probability q and $1 - q$, respectively. This setting better captures the characteristics of many modern IT service centers and it creates two management challenges for the owner.

First, while the owner only knows the distribution of the expected base demand θ, the manager running the center often has better knowledge about the realized market condition θ. The owner would like to solicit market information from the manager so that she can make proper capacity investment to meet the service standard. However, the manager, with his own agenda, may not truthfully share market information with the owner. Second, because of demand uncertainty, the owner cannot observe and has no means of directly verifying the manager's effort level. While the owner would like the manager to exert the optimal marketing effort to maximize the owner's net benefit, the manager has a different interest because for an effort level α he incurs a disutility $V(\alpha) = \alpha^2/2$, which is increasing and convex in α. Thus, the owner has to design proper incentive contracts to induce the manager to reveal true market demand information and exert the desired level of marketing effort. And the compensation contract should be based on observable variable such as the number of requests processed.

Let N be the number of requests, which is a random variable. Following general principal-agent adverse selection model, see [5, 6, 7, and 11], among others, we also assume risk neutral principal and agent. Let $s(N)$ be the compensation to the manager and M be the manager's net utility from an outside alternative. Thus, the manager will choose an optimal effort level to maximize his net utility given by compensation minus disutility of effort $E_N[s(N)] - V(\alpha)$ and he will accept the contract $s(N)$ only when his expected net utility is no less than M.

For the owner, a common solution for the adverse selection problem is to offer a menu of contracts to the manager; each contract is designed for an expected base demand θ_i. By observing the contract selected by the manager, the owner is able to infer the true market information and invest in an appropriate capacity level. We focus on linear contract in the form of a fixed payment (or charge) plus a per-unit payment term. We choose linear contract for its implementation simplicity and popularity in practice. We develop two incentive compatible contracts: (i) variable rate contract $s_i(N) = f_i + b_iN$ which offers different per-unit rates (b_i) and fixed payment term (f_i) for different market conditions (θ_i); (ii) uniform rate contract $s_i(N) = pN - F_i$ which offers a fix per-unit rate (p) regardless of market condition and charges the manager F_i for using capacity μ_i. Observing the realized market demand, the manager reports to the owner (or selects a contract offer), and the manager may or may not report truthfully to the owner.

Following the revelation principle [9], we only need to search for the optimal menus of contracts from the class of truth-telling contracts, under which it is in the manager's interest to truthfully reveal market information to the owner.

3. Contract analysis and numerical example

In this section, we analyze the results under the two proposed contracts and compare them with the first-best outcome. The first approach offers a menu of linear contracts composed of different fixed payments and commission terms. The manager is responsible for reporting the realized market condition by selecting a contract from the menu. The owner is responsible for capacity investment and meeting the service standard, based on the manager's report of market information. The second approach involves a payment to the manager at a fixed per-unit rate regardless of the market condition, and different charges to the manager for using different levels of capacity. The manager is explicitly responsible for capacity selection and meeting the service standard. The owner can solicit true market information by manipulating the charge for capacity.

While both contracts can solicit true market information from the managers, the uniform rate contract can even induce the first-best effort levels from the manager. However, because of information asymmetry, the owner has to incur a cost (compensating more to the manager) for soliciting truthful market information under both contracts. Thus, the owner realizes less expected profit when the manager possesses private information on market demand and his effort level. However, the owner can improve her profit by selecting which contract to offer based on the demand distribution.

Through profit comparison we find that when the probability of having a low demand market is higher than that of a high demand market (i.e., $q < ½$), the owner can realize a higher expected profit level by offering the uniform rate contract. This is mostly because the uniform rate contract achieves the same profit level as in the full-information case when the expected base demand is low. However, when the probability of having a high demand market is greater than ½, the owner is better off to offer the variable rate contract. This is because the variable rate contract leads to a higher profit level in the high demand market and this profit improvement can offset the profit shortage in the low demand market, especially as the probability of having a low demand market is relatively low.

We illustrate the results in a simple numerical example. Consider a service center such as a computerized medical imaging center which is characterized with the following parameter values: $r = \$80$, $c = \$30$, $W_0 = 0.1$, $M = \$100$, $k = 0.7$, $\theta_l = 30$, $\theta_h = 45$, and q, the probability of having a high demand market, varies from 0.05 to 0.65. We compute the expected profits when offering the variable rate contract, the uniform rate contract, and a pooling contract, and compare them with the profit in the full-information case. Here, the pooling contract refers to a uniform linear contract $s(N) = f + bN$, i.e., the owner offers the same contract to the manager regardless of market demand. Clearly, this pooling contract does not solicit market information from the manager.

Figure 1 shows the percentage of full-information profit that can be achieved by offering the variable rate, uniform rate, and pooling contracts. We see that because both the variable rate and uniform rate contracts can solicit true market information from the manager, they outperform the pooling contract. In this example, when q = 0.05 (highly likely to have a low demand market) the investor can achieve 17.7% more profit by soliciting market information from the manager with the uniform rate contract than the pooling contract. When q = 0.65 (more likely to have a high demand market), the investor can achieve 11.9% more profit by offering the variable rate contract rather than the pooling contract. That is the manager's private information regarding market demand is valuable for the owner. In particular, the variable rate contract outperforms the uniform rate contract when there is a higher chance of having a high demand market, i.e., $q > ½$. In addition, the profit gap between the full-information case and the uniform rate or pooling contract is increasing in q. However, for certain higher probability values (q) the profit gap is actually decreasing under the variable rate contract. That is the value of optimal contract choice is increasing as the center's profitability is improved with the variable rate contract when the probability of having a high demand market is relatively high.

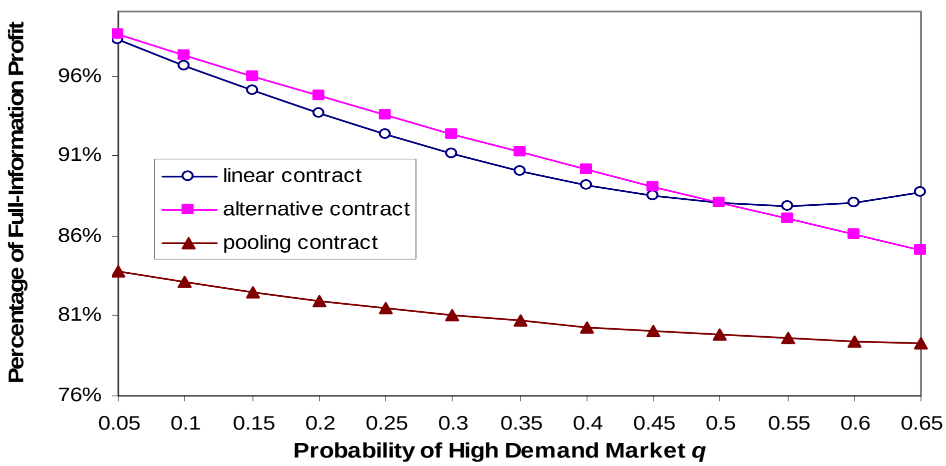

Figure 1: The percentage of the full-information profit under the linear, alternative, and pooling contracts with q varying from 0.05 to 0.65.

4. Conclusions

We study the combined moral hazard and adverse selection issue in service environment. In our model, the agent (manager) possesses private information about market demand and his own effort level, and this information is valuable for the principal (firm) since the firm is responsible for capacity investment and has to meet an industry-wide service standard. To solicit market information from the manager, the firm needs to design a menu of incentive contracts. We present two contracting approaches, both are simple to implement in practice. We are able to derive the closed-form solutions in both cases and compare them with the first-best outcome. We show that because of information asymmetry, the manager is able to reserve an information rent under both contracts. Thus, the firm's profit level is lower than that in the full-information case. We also find that the firm can improve its profit by selecting which contract to offer based on the demand distribution.

Our work extends existing literature on contract design to a new setting and contributes to current research on service resource management. By integrating resource investment and incentive contract design, firms are able to balance capacity, delay, and agency costs all together and achieve the optimal rather than suboptimal outcome when capacity and compensation decision are made separately. Our study applies to many modern IT service systems, manufacturing, and healthcare facilities and provides guidelines for firms dealing with service environment when the managers have an information advantage.

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