



## Decision Support

## Impact of cost uncertainty on pricing decisions under risk aversion

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## ABSTRACT

This paper studies cost uncertainty in services. Despite the fact that the service sector has become the largest component of gross domestic products in most developed economies, cost uncertainty and its impact on pricing decisions have not received much attention in the literature. In this paper, we first identify the root causes of cost uncertainty in services. Using the distinctive characteristics of services defined in the literature, we show why cost uncertainty, which has been widely neglected in the manufacturing dominated literature, is pervasive in services. Next, we investigate how cost uncertainty affects a risk-averse service provider's pricing decisions in a make-to-order setting. Using the expected utility theory framework, we show that cost uncertainty increases the optimal price, whereas demand uncertainty reduces it. As a result of the countervailing impacts, the optimal price under risk aversion may be larger or smaller than the optimal risk-neutral price. Next, we study the problem of optimizing cost contingency in service contract pricing. We show that the optimal cost contingency decreases as the profit of the contract increases even when the utility function exhibits an increasing absolute risk aversion. Finally, we introduce various strategies to mitigate the risk of cost uncertainty observed in practice, and propose new research problems.

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## 1. Introduction

When engaging on a service contract, service providers are uncertain about the cost of delivering the service. For example, consider a software development service provider that bids for an application development project. In the software development outsourcing industry, fixed-price contract, under which a buyer pay a fixed fee to a service provider, is one of the most common forms of contracts (Gopal, Sivaramakrishnan, Krishnan, & Mukhopadhyay 2003). To offer a fixed-price contract for the software development project, the service provider first estimates the labor and other costs to develop the application, and determines the price based on this estimate. The total labor hours required to complete the project, which determine the actual cost of the service, are difficult to estimate in advance. In software development projects, project requirements involve significant uncertainties, which often cause cost overruns (Kraut & Streeter 1995). Anecdotal examples from other service industries such as the business process outsourcing industry and the construction service industry also highlight

the significance of cost uncertainty in services. (Flyvbjerg, Holm, & Blomberg et al. 2014; Buhl 2004).

Cost uncertainty yields a substantial risk in service profitability, and thus has a huge impact on the service provider's pricing and contracting decisions. Despite its importance, cost uncertainty has not received much attention in the pricing and contracting literature. This oversight is in a sharp contrast to demand uncertainty, which has been studied extensively (see, e.g., Özer & Phillips 2010). As Shoemaker and Mattila (2009) pointed out, most existing pricing frameworks were developed in the context of consumer goods. Karmarkar and Pitbladdo (1995) argue that the very nature of service markets depends on distinctive characteristics of services. Hence, the existing pricing frameworks cannot properly address the problem of service pricing. The service sector now accounts for about 80 percent of the United States economy (New York Times 2010). Thus, cost uncertainty and its impact on pricing decisions are important subjects to explore.

In this paper, we first introduce cost uncertainty in services. The characteristics of services have been well explored in the literature. We show how each of the defining characteristics of services yields cost uncertainty, which also explains why cost uncertainty does not usually arise in manufacturing. Next, we investigate the impact of cost uncertainty on pricing decisions made by a risk-averse service provider in a make-to-order setting. In our model,

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the service provider starts delivering the service after the demand is realized, and thus quantity (production) decisions are made trivially. Using the expected utility theory framework, we model the problem of pricing under cost and demand uncertainties, and show how the two sources of uncertainty affect the optimal pricing decision. Next, we study the problem of optimizing cost contingency in service contract pricing. We show how the properties of the potential contract affect the optimal cost contingency. Finally, we introduce various strategies that service providers employ in practice to mitigate the risk of cost uncertainty, and propose new research problems.

This paper is closely related to the literature on pricing under demand uncertainty and risk aversion. In the economics and operations literature, how a seller's risk aversion and demand uncertainty affect pricing decisions has captured some attention (e.g., Leland 1972, Agrawal & Seshadri 2000, Colombo & Labrecciosa 2012, Rubio-Herrero, Baykal-Gürsoy, & Jaśkiewicz 2015). This literature, however, consistently assumes that cost is certain (or zero), and hence the impact of cost uncertainty has not been explored. The impact of risk aversion and demand uncertainty on the optimal inventory (production) decisions has been studied extensively in the operations literature (see, e.g., Ahmed, Çakmak, & Shapiro 2007, Wang, Webster, & Suresh 2009, Choi & Ruszczyński 2011). This stream of work, however, considers neither the pricing decision nor the uncertainty in cost. We contribute to the literature by introducing cost uncertainty in services, and investigating its impact on pricing decisions under risk aversion.

The pricing literature has shown that the impact of demand uncertainty on the optimal pricing decision sharply depends on the demand uncertainty model (Agrawal & Seshadri 2000, Xu, Chen, & Xu 2010). Hence, we solve the problem under three different demand uncertainty models: valuation uncertainty, additive demand uncertainty, and multiplicative demand uncertainty. We show that under all demand uncertainty models, cost uncertainty consistently increases the optimal price, whereas the impact of demand uncertainty varies depending on the model. We defer all proofs to the appendix.

## 2. Cost uncertainty in services

In this section, we explore what makes service costs uncertain. As we discussed in the previous section, cost uncertainty has been neglected in the manufacturing centered pricing literature. This oversight implies that the causes of cost uncertainty are closely related to distinctive characteristics of service. The characteristics of service have been well studied in the literature. As summarized by Sampson and Froehle (2006), there are five defining characteristics of service: intangibility, heterogeneity, simultaneity, perishability, and customer participation. Among the five, all but perishability contribute cost uncertainty in service. In this section, we discuss how the four remaining characteristics yields cost uncertainty.

**Simultaneity.** The most important characteristic of service that causes cost uncertainty is simultaneity. Simultaneity of service refers to the fact that services are produced and consumed at the same time. The consumption of service can only occur after the service provider and the buyer agree on the payment for the service. Hence, simultaneity implies that the timing of sales precedes the timing of production. For example, consulting projects begin after clients sign on contracts, and lawyers start providing legal services after clients sign on retainer agreements. In contrast, in most markets of consumer goods, manufacturers produce goods first, and consumers buy completed products from retailers. In other words, in manufacturing the timing of production usually precedes the timing of sales.

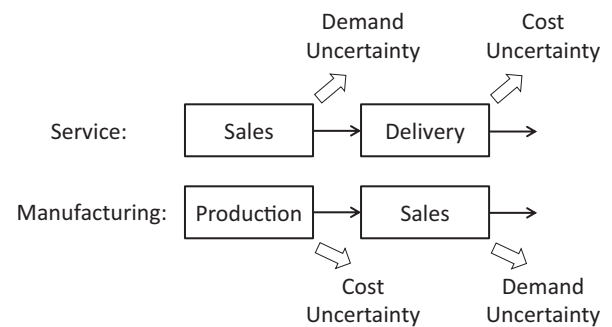


Fig. 1. Sales and production timings in service and manufacturing.

The cost of a service involves significant uncertainties until the service is fully delivered. For example, the time to complete a service job such as cleaning a house or repairing a car is uncertain until the job is finished. In the IT outsourcing service industry, service providers often deliver services using globally distributed delivery centers (Zarella 2010). In this case, the currency and inflation rates of the countries at which delivery centers are located also contribute to cost uncertainty.

The point of production completion is the time when cost uncertainty is fully resolved. Similarly, the point of sales is the time when demand uncertainty is realized. Customers make purchasing decisions based on prices, which means that pricing decisions are made before the point of sales. Hence, as shown in Fig. 1 the fact that delivery follows sales implies that service providers make pricing decisions in the presence of cost uncertainty. Off-shore production is also common in manufacturing, which implies that production cost in manufacturing can be also uncertain. However, because production precedes sales in manufacturing, cost uncertainty is fully resolved before consumers make purchasing decisions for manufactured goods.

**Intangibility.** The second characteristic of service that yields cost uncertainty is intangibility. The price of a manufactured good is not always determined after production is fully completed. For example, computer manufacturers may adopt assemble-to-order strategies under which final assembly of products is done after customers place their orders (Oh, Sourirajan, & Ettl 2014a). In other words, pricing decisions for manufactured goods can also be made before the production is completed, i.e., under cost uncertainty. However, even in such cases, the degree of cost uncertainty faced by manufacturers is minor compared to that faced by service providers. The production cost of manufactured goods is highly dependent on tangible objects such as raw material costs and component costs. Such costs are relatively easy to quantify and predict. In contrast, service costs critically depend on intangible objects such as skill and knowledge levels of workers and their productivity. These key determinants of service costs are difficult to measure, and highly variable. The productivity of a worker changes daily and the skill level improves over time yet at variable rates. Hence, estimating service costs is much more challenging than estimating production costs.

**Heterogeneity.** The third characteristic of service that yields cost uncertainty is heterogeneity. In manufacturing, most goods are produced via mass production, and the production processes are highly automated. Hence, there is a minor variability in the production costs of the same product. In contrast, every service is custom because service production is fundamentally driven by customers' inputs (Spohrer, Maglio, Bailey, & Gruhl 2007, Roels 2014). Thus, delivery costs of the same type of services are all different.

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