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Product quality selection: Contractual agreements and supplier competition in an assemble-to-order environment

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ABSTRACT

We consider a multi-supplier, single-manufacturer supply chain where each supplier sells a different component at varying quality levels. The manufacturer has to decide on which quality level to choose for each component, trading-off the total cost and total quality. Each supplier decides on a price per unit quality level for its component. We characterize the strategic interaction among the suppliers and analyze the inefficiencies. We find that the inefficiencies due to such quality competition can be quite significant. We then propose and analyze several mechanisms, such as quality-price schedules and revenue sharing, that restore efficiency.

1. Introduction

Selecting the quality of different components used to build a product is a key challenge for manufacturers. Car manufacturers need to make decisions on the performance of the engine, the quality of the interior seating materials, the suspension and brake systems, etc. Similar component selection problems arise in aerospace manufacturing, consumer electronics and even home remodeling; each is characterized by a situation where the product quality is a function of the quality of its many individually-supplied components. On the other hand, customers generally have price points in their mind before making a purchase decision. For example, a customer who wants to have the highest performance engine for the car he is about to buy with several convenient options, may have to consider a less-known brand if all these come at a higher price with the brand he initially had in mind. Similarly, a customer that is about to buy an IPad who also does not want to pass a certain price point may have to do the necessary trade-off between (16 GB, with 3G) and (32 GB, no 3G) configurations. We can think of several such examples in different industries.

We have encountered this problem as well during a research project with a leading semi-conductor company which designs, manufactures and sells CPUs whose quality (in this case performance) varies. The firm was able to charge more for higher quality parts and earned higher margins on those parts because costs were roughly the same for all quality levels. As a result, they wanted to encourage their customers (computer manufacturers) to build systems using higher quality parts. They were concerned, however, that their current pricing structure might not create the right "sell up" incentives.

One of this firm's main customer groups are resellers. A reseller builds no-brand computers which compete with larger OEMs on the market. They source different components such as hard-disk, CPU and memory from various suppliers and assemble them into a computer. While large OEMs can sell to several market segments profitably, because these resellers do not have the brand name advantage, it becomes even more critical for them to identify the "right segment" and build a product that has the highest *value* for a given budget. This way, they can sell the same configuration that a large OEM sells at a cheaper price and compete more comfortably in that segment. Throughout the rest of the paper, we will refer to a reseller as "manufacturer" and the upstream component providers as "supplier" (including the semi-conductor company that provides the CPUs). As shown in Fig. 1, when deciding on the bill-of material for the computer, a manufacturer needs to choose quality levels for each component. For example, they could design a system with a 2.8 GHz CPU, 140 GB hard disk and 1 GB memory or one with a 2.1 GHz CPU, 100 GB hard disk and 2 GB memory. Each component is vertically differentiated, meaning that a higher quality part is preferred over a lower quality one all else being equal. The problem the manufacturer faces is to optimally balance the total cost and total quality of their final product so as to obtain the highest value product that will give them the necessary pricing flexibility while competing with more branded counterparts. It might be that

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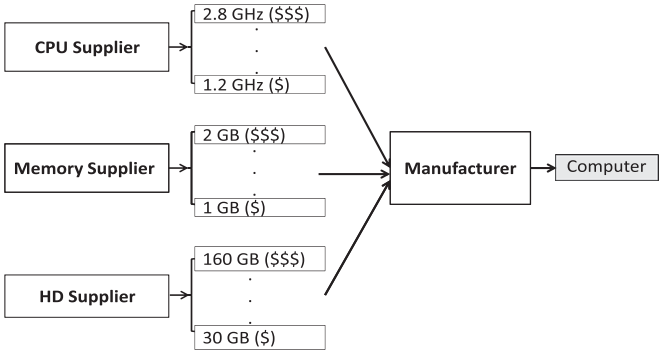

Fig. 1. Computer manufacturer example.

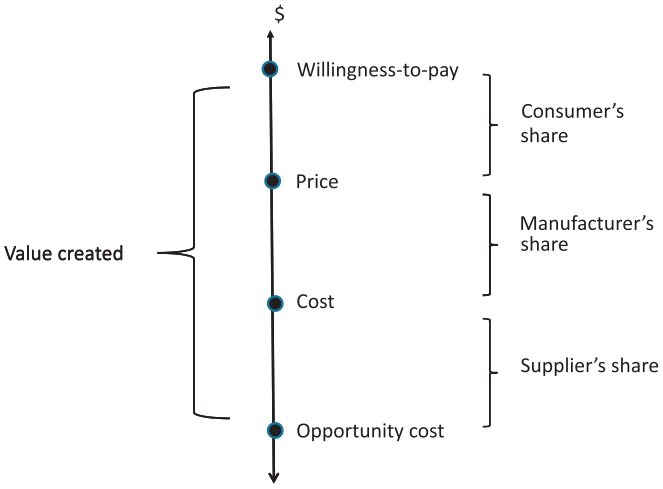

Fig. 2. Value creation.

a product with very high performance designed for the highest segment may not be perceived as "high value" by this kind of reseller as it may also cost too much leading to very minimal price flexibility when competing with OEMs.

The CPU supplier wanted to encourage the manufacturer to build systems with higher quality (and more profitable) components. On the other hand, other suppliers providing different components also wanted to sell higher quality parts. The result was a *competition among components* for share of the manufacturer's total design budget.

To model this situation, we view the manufacturer's decision as a strategic design problem in which it maximizes the difference between the product value and its cost; that is, we assume the manufacturer attempts to maximize the *added value* of its design. We assume that how this added value is translated into total profit is a later-stage decision. This is in parallel to the value appropriation theory discussed in Brandenburger and Stuart (1996). For example, the firm could price the product close to its value (minimize consumer surplus) and make high margins on a low volume of sales; or it could price close to cost (maximize consumer surplus) and make a low margin on a high sales volume; or most probably it would adopt some strategy in between. We do not analyze this pricing decision however, and assume that it is made after the design decision. Fig. 2 from Brandenburger and Stuart (1996) illustrates the main idea of such value maximization.

Each component supplier, in turn, needs to decide on a wholesale price per unit quality level of its component. As a supplier increases its wholesale price, its margin increases, but the quality level of that component selected by the manufacturer will decrease. We characterize the strategic interaction among these suppliers and show that the quality levels that the manufacturer selects in equilibrium from each supplier are lower in a decentralized system than in a centralized system. This means the final product built in a decentralized system will be of less value. In other words, a consumer will be paying more for less. Furthermore, we show that the inefficiency loss could be as high as 60% depending on the business environment telling us that its mitigation can result in substantial savings for the entire supply chain, which in turn means more value for the final customer. We explain this using various industry examples. We then identify potential contracts and mechanisms such as revenue sharing and quality-price discounting that restore efficiency.

As an extension to this problem, we consider another model where we assume a fixed exogenous price for the final product (a "target price point") and both quality dependent cost and demand in the profit function of the manufacturer. This helps to test the robustness of our earlier coordinating mechanisms. To simplify this more complex case, we assume that the quality levels for all but one component are fixed and that the manufacturer decides on the quality of only one of its components. We again first study the system inefficiencies and show that the same revenue sharing and quality-price discounting mechanisms that we studied earlier still enable the system to achieve full coordination.

2. Literature review

Our work is relevant to four different research streams: vertical differentiation, supply chain contracting and coordination, bundling and product design.

Vertical differentiation is an important area of research in economics and marketing. Quality in this literature generally refers to the level of some attribute, such that higher quality is always preferred by the consumer to lower values. For example, one would prefer a faster processor over a slower one ceteris paribus. The same is true with a higher resolution vs. lower resolution LCD TV. This is in contrast to horizontally differentiated products in which there is no dominant ordering on the attribute of the product; for instance, not everyone prefers red over blue cars.

Mussa and Rossen (1978) is a seminal paper in this area. They consider a monopolist selecting quality positions when serving a market with consumers that have heterogeneous valuations for quality. Moorthy (1984) looks at the same problem with a different model in which consumers self-select the product they purchase. They conclude that firms may need to provide high-value customers with their preferred quality and distort the quality of the lower product.

These monopolistic models have been extended to take into account competition. Gabszewicz and Thisse (1979) is the earliest paper that considers the effect of competition in vertically differentiated environments. Shaked and Sutton (1982), Gal-Or (1983), and Moorthy (1984) assume an environment where firms compete on not only quality but other decisions such as price and quantity and the main finding is that firm should differentiate the quality of the product to avoid competition in other dimensions.

Almost all papers in this literature assume that the firms sell their products directly to the market without any intermediary. Hence the incentive issues were never discussed. Villas-Boas (1998) is one paper that considers such an intermediary when selling vertically differentiated products, but their main focus is on choosing quality positions within a product line and not necessarily coordination or competition issues as we do. Furthermore, they consider a one supplier, one retailer setting which is different than the multi-supplier model we consider. To the best of our knowledge, this is the first work that contributes to this