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Outsourcing vs. in-house production: a comparison of supply chain contracts with effort dependent demand

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ABSTRACT

We analyze the effort and pricing decisions in a two facility supply chain in which one of the parties can exert costly effort to increase demand. We consider an outsourcing model in which the supplier makes the effort decision and an in-house production model in which the manufacturer decides on the effort level and we compare these two models with each other. We analyze and compare several contracts for decentralized supply chain models and we aim to find which contracts are best to use in different cases. We find the optimal contract parameters in each case and perform extensive computational testing to compare the efficiencies of these contracts. We also analyze the effect of the powers of the parties in the system and the effect of system parameters on the performances of the contracts and on the optimal values of the model variables such as price, effort and demand.

1. Introduction

In this study, we analyze a supply chain composed of two parties and we aim to increase the efficiency of this system through contracts. For this study, we are motivated by an original equipment manufacturer (OEM) that works with a contract manufacturer (CM) for the production of one of its products. The OEM (manufacturer) outsources the production to the CM and the CM invests in the technology and expends a certain amount of effort for the production of this product. A larger investment in technology or a higher level of effort improves the quality of the product and a higher quality product results in an increased market potential (demand) for the product. In this setting, the CM essentially determines the product quality. However, the OEM is worried that the CM does not exert the appropriate level of effort to produce products of the appropriate quality. Thus, the OEM is considering to use a contract in order to effect the supplier's effort and to increase the demand and his profits. However, the OEM cannot force the CM to exert the level of effort that the OEM wants. It is assumed that the companies cannot contract directly on the effort level (or the quality level) beforehand since quality is not always verifiable for a third party such as a court to decide on. In addition, the firms cannot identify every possible contingency and define effort in advance. Thus, they cannot write a complete contract that defines what to do in every possible situation. Because of these reasons, we assume that the quality and thus the efforts of the parties are non-contractible which is a standard assumption in much of the related research (see [1–5]).

In today's world, there might be many reasons for an OEM to outsource the production of a product to a CM, such as the OEM might not have the required technology to make that production or outsourcing might be less costly for the OEM than in-house production. In addition, as stated by Yue et al. [6], Sawik [7] and Yu et al. [8], quality, capacity restrictions, probabilities of satisfying due dates, disruption risks, discounting schemes, reliability and flexibility of the suppliers effect the outsourcing and supplier selection decisions. In this study, we mostly focus on the cost and the quality considerations of the OEM. Since the OEM is worried about the effort level of the CM and the quality of the products, instead of outsourcing, he also considers in-house production to determine the product's quality level himself. However, since the OEM is not as experienced in the production of the product as the CM, he might need to put more effort in production and make more investment in order to produce the same quality product that the CM produces. Thus, the effort might be more costly to the OEM compared to the cost of effort to the CM. In addition, the unit production costs for the CM and the OEM might differ from each other. The cost of production for the CM might be less than the cost of production for the OEM due to various reasons like the specialization of the CM in the production of that product or the low labor costs in the geography of the CM. However, even in those cases, the OEM can still choose to make the product himself by investing in the necessary technology for

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the production and by incurring the high production costs. Also, note that the OEM still needs to buy some raw materials from a supplier for in-house production and we assume that the OEM still uses contracts in his relationship with his supplier in the in-house production case.

Several different types of contracts are analyzed in literature in different settings (see [9–13], for surveys on supply chain coordination with contracts). Major coordination mechanisms include profit or cost sharing mechanisms, linear two part tariffs and discounts. Profit sharing mechanisms are designed to share the benefit of coordination and cost sharing mechanisms are designed to share the total cost of the supply chain between the supply chain members, whereas a two part tariff is a price discrimination technique in which the price is composed of a per-unit charge and an additional fixed fee. Quantity discount is the offer of price discount in return for increased order quantity.

It is shown that, although a contract can be very efficient in some cases, it might not perform as efficiently in some other situations. Thus, the choice of the contract to implement in the supply chain also plays an important role in coordination. Companies need to determine the right type of contract to implement depending on the specific characteristics of their business structure and the parameters of their system. In literature, researchers mostly analyze contracts in isolation from each other and aim to find fully coordinating contracts that allow arbitrary profit sharing which is defined as contracts that make the total profit of the decentralized supply chain equal to the total profit of the centralized supply chain and allow each party get an arbitrary portion of this profit through the contract parameters (see [11]). However, in some cases, finding a fully coordinating contract might not be possible or even if such a contract is found, it might be too complex, costly or hard to implement due to various reasons. Note that, the supply chain members may need to implement new information technologies or control systems to facilitate an effective use of some of the contracts. In addition, some companies might prefer some contracts over the others due to the risks in the contracts and special circumstances of the relations in the supply chain. Thus, in those cases, there might exist simpler, less costly and easier to implement contracts which cannot fully coordinate the supply chain but have a good performance for the system objectives. These non-coordinating contracts might be preferred by the supply chain members to the coordinating ones depending on the performance of the contracts, implementation costs and system characteristics.

In this study, we will analyze two different models for supply chain coordination; the supplier effort (outsourcing) and the manufacturer effort (in-house production) models. There are several papers in literature that analyze contracts considering manufacturer or retailer effort (e.g. [14–17] etc.). For the manufacturer effort case, Cachon [11] states that coordination with an effort-dependent stochastic demand model is complex when the firms are not allowed to contract on the effort level directly. He states that the supplier fails to coordinate the supply chain with buy-back, revenue sharing, quantity flexibility or sales rebate contracts. Taylor [14] shows that he can coordinate the channel by combining a sales rebate contract with a buy-back contract. However, four parameters make for a complex contract. He et al. [17] also consider a variety of contracts to coordinate a supply chain with sales effort and price dependent stochastic demand. They show that none of the traditional contracts such as a returns policy or a revenue sharing contract can coordinate the supply chain and only the properly designed returns policy with sales rebate and penalty contract is able to achieve channel coordination. Krishnan et al. [15] also analyze the manufacturer effort and discuss coordinating contracts in this setting. Cachon and Lariviere [19] show that revenue sharing contracts cannot coordinate this supply chain, but they present a simpler quantity discount contract that achieves coordination. Netessine and Rudi [18] can also coordinate this supply chain by presenting a contract that requires simultaneous revenue and cost sharing. In addition, a linear two-part tariff contract can also coordinate the supply chain in the manufacturer effort model.

In our supplier effort models, although the effort is not contractible, we assume that once the supplier exerts the effort, the manufacturer can observe and act upon it, which is a standard assumption in much of the related research (see [4,5]). So, when the CM exerts the effort, different from OEM-effort models, the OEM can observe the CM's effort, and act (set the sales price) accordingly. Reyniers and Tapiero [20] and Baiman et al. [21,22] analyze the supplier effort in a quality context in which the effort defines the quality of the product. Similarly, Chao et al. [24] assume that the supplier effort effects the quality level and thus effects the amount of recalls after production. They analyze two different types of cost sharing contracts based on root cause analysis under symmetric and asymmetric information in this setting and discuss their results. Zhu et al. [25] consider an outsourcing model where the buyer and the supplier both incur quality-related costs and they show that the buyer's involvement has a significant impact on the profits. They also investigate how quality-improvement decisions interact with operational decisions. Lal [23], Chu and Desai [2] and Gilbert and Cvsa [4] also examine supplier effort in different settings, analyzing different types of contracts. We observe in this study that coordinating the supply chain in the CM effort model is not as easy as coordinating the supply chain in the OEM effort model and more complex contracts are required to coordinate the supply chain in the CM effort model.

In this paper, different from the literature, we do not specifically look for a coordinating contract but focus on the non-coordinating contracts, as well as the coordinating ones, find the optimal contract parameters and compare the performances of different contracts with respect to each other, in a setting where the market demand is a function of the market price and the effort level of the supply chain members. We also consider the powers of the supply chain members and analyze how the power structure in the system effects the outcomes of the contracts. We compare the contract performances with each other and with coordinating ones and aim to find which contracts are best to use for the companies under different situations and if it is worthwhile to look for a complex, coordinating contract when the simpler, well-known contracts cannot fully coordinate the supply chain. We also analyze how the market variables such as market price, demand, effort and profits of the supply chain members are affected with different contracts by the system parameters such as market size, price elasticity of demand, cost of effort, unit cost of production and powers of the parties. In addition, we compare the supplier effort and manufacturer effort models with each other and aim to find under which conditions in-house production is preferred to outsourcing for the manufacturer. In this paper, we aim to answer questions such as: (i) How big is the performance difference between a coordinating contract and a simpler non-coordinating one, and among the simpler contracts, which one is the best to use for the OEM and the CM under different parameter settings? (ii) How are the efficiencies of the contracts affected by the system parameters? (iii) How do the powers of the parties affect the contracts? (iv) What are the effects of different contracts on the system variables such as the market price, quality level and demand? (v) When should the manufacturer move to in-house production, when should he continue outsourcing and which contract should he use in either case?

We start our analysis by explaining our general model in the next section. Then, we analyze the centralized supply chain model in