



## Outsourcing structures and information flow in a three-tier supply chain

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### ABSTRACT

We consider a three-tier supply chain consisting of an original equipment manufacturer (OEM), a contract manufacturer (CM) and a supplier. We analyze and compare three outsourcing structures that are currently implemented by top-tier OEMs: (1) inhouse consignment, under which the OEM signs independent contracts with the CM and the supplier; (2) turnkey with integration, under which the OEM contracts with an alliance of the CM and the supplier; and (3) turnkey, under which the OEM contracts with the CM, and the CM then subcontracts with the supplier. The OEM is a Stackelberg leader who decides how much of the end product to produce. All parties use take-it-or-leave-it wholesale-price contracts. Both the CM and the supplier have private information about their own production costs. The OEM has prior information about these costs, but this prior information depends on the specific outsourcing structure. Each party's optimal decision is characterized. We then compare each party's profits across the three outsourcing structures and identify which benefits and when.

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### 1. Introduction

Today's advanced information, communication and transportation technologies, as well as the increasingly open global economy, are providing unprecedented opportunities for companies to outsource more of their traditional business activities. For example, computer makers and other original equipment manufacturers (OEMs), such as Motorola, IBM Corp., Hewlett-Packard Co. (HP) and Dell Computers, which traditionally produced inhouse, now often outsource their production to contract manufacturers (CMs). By so doing, these OEMs hope to better focus on their core competencies, such as product design and marketing. They also expect to enjoy cost savings due to the CMs' economies of scale and flexibility. However, production outsourcing is also risky: what is being outsourced also involves tacit knowledge and supplier relationships, which may eventually hurt the competitive advantage of the OEM. Many OEMs have learned this lesson the hard way and have started to restructure their outsourcing arrangements so as to have more control over supplier relationships. According to Carbone (2004), Wolfgang Zenger, vice president of HP's global procurement services group, said that in the 1990s HP outsourced a lot of its strategic purchasing and manufacturing to electronics manufacturing

services (EMS), which proved to be a mistake: "We had given too much control to contract manufacturers", he said. HP lost a lot of visibility in the supply chain because its relationships with suppliers were not as tight as they should have been. "So we took some control back in house through the buy-sell process", he said. For more examples of different outsourcing arrangements, see Amaral et al. (2006).

Although a great deal of research has been carried out on the coordination of decentralized supply chains under a given outsourcing structure, little attention has been paid to a comparison of the effectiveness of different structures (e.g., which party carries out material purchasing, the OEM or the CM). This paper takes a first step in this direction and investigates several commonly seen outsourcing arrangements. Our focus is on how different structures may affect the information flow in the supply chain and thus affect the chain partners' decision making. We further examine the consequent impact on the performance of each player and that of the entire chain.

We consider a three-tier supply chain consisting of an OEM, a CM and a supplier. The OEM owns the brand and outsources production, but retains contracting power. Consider the following three outsourcing structures.

- Turnkey ( $T$  for the superscript). In this structure, the CM is responsible not only for manufacturing, but also for managing the upstream supply chain, including material purchasing from the supplier. For example, such consumer electronic companies as Ericsson and Palm outsource the entire

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manufacturing of their products from CMs such as Flextronics (Huckman and Pisano, 2004).

- Turnkey with integration (*integration* for short; *I* for the superscript). In this structure, the CM and the supplier form an alliance. The OEM contracts with the integrated party through the CM.
- Inhouse consignment (*consignment* for short; *C* for the superscript). In this structure, the OEM contracts separately with the CM and the supplier. The CM is responsible only for manufacturing. The OEM negotiates and purchases materials from the supplier directly; once purchases are completed, the ordered components are shipped from the supplier to the CM (Carbone, 2004). This arrangement is often facilitated by the evolution of online auctions and e-purchasing, and has been employed by many top-tier OEMs in recent years. For example, HP has established an automated global e-procurement system to handle instantaneous buy-sell transactions with its suppliers.

These three outsourcing structures have different material, information and cash flows. We assume that the end product has price-dependent deterministic demand. The OEM is a Stackelberg leader who sets a price point (“target price”) at which the end-product will be sold. A good example is the retail furniture chain IKEA, which first sets the target price for its product, and then chooses a manufacturer to produce that product (Margonelli, 2002). As a result, it also determines the production quantity of the end-product. Under consignment, the OEM offers wholesale prices to the CM and the supplier; under integration, the OEM offers a wholesale price to the alliance of the CM and the supplier (alliance for short); and under turnkey, the OEM offers a wholesale price to the CM, which subsequently offers another wholesale price to the supplier.

The unit production costs of the CM and the supplier constitute private information, and the OEM has only prior knowledge of them. However, the prior knowledge of the supplier's cost depends on the specific outsourcing structure. For example, under turnkey, the outsourcing supply chain management activities (procurement, control and the allocation of product availability) to the CM loosen the relationship between the OEM and the supplier. Thus, the former has little information about the latter's cost. Switching from turnkey to consignment, in contrast, allows the OEM to obtain more information about material costs. In other words, the OEM has vaguer information about the supplier's costs under turnkey or integration than it does under consignment.

Our primary interest in this research is to better understand how cost information asymmetry affects supply chain performance under the different outsourcing models.

We first consider one-period contracts. We find that under all outsourcing structures considered, it is not possible to achieve credible information sharing between the OEM and the CM without a suitable mechanism because the CM always has the motivation to provide stochastically larger prior information (in the sense of the reverse hazard rate order) when it is asked for it. We find that when the OEM is able to obtain the same level of information on the other parties' costs across the three structures, it is always better off under integration than under consignment or turnkey. We argue that integration mitigates double marginalization in the supply chain. However, there is no certain answer for the comparison result between consignment and turnkey. Consignment offers an information advantage and reduces the middle party for the OEM; however, under turnkey, the decision rights are delegated to the more reasonable party, the CM, as it has private information on its own production costs and can make a more reasonable decision on the wholesale price.

We then investigate a two-period model. The setting for each period is similar to the single-period model. However, the players can update their prior information at the end of period 1, and a wholesale price contract can be renegotiated at the beginning of period 2. We derive the subgame perfect Nash equilibriums under consignment and turnkey. One of the major findings here is that, even when the OEM's prior information on the supplier's cost under turnkey is in the best interests of the CM, the OEM can now be better off under turnkey than under consignment. Therefore, the OEM's and CM's objectives can be aligned under turnkey. One possible explanation is that when the game lasts for two periods, the CM or the supplier may pretend to have high costs in the first period in expectation of a higher wholesale price in the second period. Such gaming behavior results in losses for the OEM. Turnkey helps to mitigate this gaming effect, whereas consignment strengthens it.

Given that production contracts usually last more than one period in practice, the findings presented here can be summarized in one word: *Caution*. The choice between turnkey and consignment depends on specific situations: to what extent the cost information can be observed, how many periods the contract lasts, etc.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 considers one-period contracts, and Section 4 considers two-period contracts. Section 5 presents our numerical results, and Section 6 concludes the paper.

## 2. Related literature

Our work is mainly related to two streams of the supply chain literature. The first considers contract design with asymmetric information. The other addresses dynamic games with renegotiable contracts. As detailed in the following, our model setting and focus are quite different from those of previous work.

Many researchers have investigated supply chain contracting issues under demand information asymmetry. A typical setting consists of a supplier and a manufacturer. The latter can observe real demand, but the former knows only the demand distribution. The main thrust of those research is that the supplier design a contract to induce the manufacturer to reveal the demand information truthfully. Representative studies include those of Blair and Lewis (1994), Porteus and Whang (1999), Cachon and Lariviere (2001), Özer and Wei (2006) and Burnetas et al. (2007) and the references therein. See Cachon (2003) and Chen (2003) for reviews. Recently, Ülkü et al. (2007) consider a situation in which the CM and the OEM differ in their forecast accuracy and resource pooling capabilities, and investigate the effectiveness of premium-based schemes in inducing the best party to bear the demand risk. In contrast, we consider a deterministic price-sensitive demand. Once the OEM decides what wholesale prices to contract with the upstream players, the market selling price and the production quantity are determined. Therefore, demand information is not an issue here.

Instead, our work is more closely related to contract design issues under asymmetric cost information. One of the earliest studies along this line was that carried out by Corbett and Tang (1998). They assume a linear price-sensitive deterministic demand and consider a supplier that offers a contract to a buyer, but knows the buyer's marginal cost only through prior distribution. They show that by designing a two-part menu of nonlinear contracts, the supplier can induce the buyer to reveal its true cost. Corbett and de Groot (2000) and Corbett (2001) study the cost information asymmetry issue in the context of EOQ and  $(r, q)$  inventory models, respectively. Ha (2001) extends Corbett and Tang's (1998) model to a price-sensitive stochastic demand

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