



A game-theoretic approach to transfer pricing in a vertically integrated supply chain

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ABSTRACT

We study the problem of setting transfer prices in a vertically integrated supply chain, in which the divisions share technology and transactions costs. We develop a cooperative game that provides transfer prices for the intermediate products in the supply chain. This model is applied both when the market prices for these products are known and also when their valuations differ. We provide a solution that is fair and acceptable to all divisions. In the perfect information case, the Shapley value generates the transfer prices, while in the asymmetric case we obtain transfer prices from the solution to a linear program.

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1. Introduction

The problem of transfer pricing—how to price goods that are sold between subsidiaries or divisions of a firm—has been of interest to managers, accountants, and economists for many years. Since the appearance of a seminal paper by Hirshleifer (1956), there has been a flood of articles in the literature proposing mathematical models that attack this problem. Much of this literature includes the use of market prices, production costs, or negotiation, or else develops pricing methodologies based on mathematical programming and game theory. In this paper, we propose a new game-theoretic approach to solve for transfer prices along the supply chain in multi-echelon corporations in which each division independently purchases goods from outside as well as from upstream in the supply chain, and in which the divisions share certain overhead costs among themselves.

A natural objective in determining transfer prices is fairness. To provide some background, note that cooperative game theory has been brought to bear on cost accounting problems since the 1960s. Shubik (1962)

introduced game theory into cost accounting in the allocation of joint costs at the corporate level. Hamlen et al. (1977, 1980) and Callen (1978) further applied cooperative game theory to cost allocation. These early cost allocation papers, however, did not directly treat transfer prices.

Baumol and Fabian (1964) were the first to apply linear programming (but not game theory) to the transfer pricing problem. Merville and Petty (1978) also used mathematical programming to set transfer prices for a (multinational) firm. Their model, however, does not treat production aspects such as purchase costs and shared technology costs as does the present paper.

Manes and Verrecchia (1982) studied a centralized organization with given production capacities, market prices and variable costs. They divided the budgeted gross profit using the Shapley value, and then obtained transfer prices. Their approach does not consider transactional and operational efficiencies of coalitions of divisions, or price asymmetry, as does the present paper.

Emmanuel and Gee (1982) developed a procedure to set transfer prices in a multi-divisional company, aiming to minimally discriminate against either a purchasing or a selling division. Kriens et al. (1983) carry out a one-period, static analysis that uses a linear program with and without a market for intermediate goods. Neither of these

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papers, however, treats the same problem that we do or employs cooperative game-theoretic methodology.

There are several more recent papers that employ game theory, mathematical programming, and negotiation in order to determine transfer prices. Si et al. (1993) proposed the use of the Shapley value for transfer prices, but did not implement a scheme to obtain them. Wettstein (1994) provides a mechanism to obtain transfer prices for an n -division firm. Luft and Libby (1997) examine managers' judgments about the influence of market prices on transfer price negotiations. Alles et al. (1998) study control systems designed to reduce temptation for managers in decentralized organizations to misrepresent data in transfer price negotiations. Gabrielsen and Schjelderup (1999) find that jointly owned production units, as compared to integrated firms must have motivation other than those of production efficiency and ease of decision-making. Goetschalckx et al. (2002) study a global supply chain and construct a mathematical program to set transfer prices that maximize after-tax profit subject to constraints given by national tax authorities. Gjerdrum et al. (2002) consider a two-echelon supply chain and develop a mixed-integer nonlinear programming model that employs the Nash bargaining solution, to find transfer prices and production and inventory levels that optimize profit. Wang and Gerchak (2003) study capacity planning decisions with a supplier and an assembler of a good; in these games the capacity decisions depend on the transfer prices. Yao et al. (2008) analyze a supply chain with one supplier and two competing retailers, in which, first, the retailers decide whether to share their private information with the supplier; next, the supplier reveals its wholesale price to the retailers; and finally the retailers set their selling prices. The parties are adversarial and not vertically integrated, and thus do not share costs.

None of these studies treats the problem that we study, namely, how to determine transfer prices in a vertically integrated, multi-echelon supply chain with inputs and outputs at each level, shared technology and transaction costs, and both symmetric and asymmetric information about the market costs of the intermediate goods. Only Manes and Verrecchia (1982) use the Shapley value, but in a differently structured application.

The contribution of the present paper is twofold. First, when a vertically integrated supply chain shares technology and transactions costs, we show how to incorporate the resulting efficiencies or inefficiencies into fair transfer prices that are paid when intermediate goods are sold within the supply chain, assuming that the prices of the goods are agreed upon between divisions. In this case the market prices are common knowledge, but these prices are then adjusted to reflect the shared costs across all divisions. Further, we identify a large class of situations for which all divisions in the supply chain benefit from the shared cost structure. Our second contribution is to show that fair transfer prices can be determined in a vertically integrated supply chain even when the valuations for intermediate goods are asymmetric, i.e., not agreed upon. In this instance there is no unique market price to fall back on but under reasonable conditions we can nevertheless

compute a fair set of transfer prices that incorporate the shared costs and are consistent with all divisions' valuations.

There is recent literature on transfer pricing that describes issues of informational exchange that are relevant to this paper. An Ernst & Young global survey (1999) indicates that 73% of managers find transfer pricing to be an important component of maximizing operating performance. But since managers from different divisions cooperate and compete, Dikolli and Vaysman (2006) discuss situations in which information exchange capabilities across multiple divisions of an organization range from "coarse information-technology," where the transfer of divisional information to top managers is limited, to the "perfect-IT" scenario in which local information can be made transparent across divisions with no cost. Of course, even in the perfect-IT case there is room for false reporting and other sources of information asymmetry, for example, when two suppliers report different prices. We will treat two aspects of this informational asymmetry below. Further, Dikolli and Vaysman note that valuable time is wasted in organizations when managers bargain over transfer prices; the transfer pricing mechanisms we present in this paper are in part developed to save managerial effort and provide equity.

The structures of the supply chains that we treat are frequently found on the global stage. Wilhelm et al. (2005) describe a common type of manufacturing application in which parts are shipped from US plants to border towns, and are then cross-docked over the border into Mexico to an assembly plant whereby subsequently, finished products are shipped back to the US for distribution. Such systems typify the vertical integration that is captured in our model. Also, there is much empirical evidence that transfer pricing is an important component of transactions costs for vertically integrated firms. According to Shelanski and Klein (1995), the primary focus of vertical integration is whether to "make or buy." They cite more than a dozen empirical studies that focus on transactions costs (including transfer prices) for vertically integrated companies. Tang (1992) conducted a survey regarding transfer pricing practices of Fortune 500 companies. Of the 143 respondents in the survey, 132 of used at least one transfer pricing method. Of those, 36.7% used market-based prices; 46.2% used cost-based methods, and 16.6% used negotiated prices. Among the companies relying on cost-based methods, 7.7% used variable costs of production while the other 38.5% used full costs of production (sometimes with markup).

Alles and Datar (1998) cite the Tang data in the context of developing justifications for different approaches to transfer pricing for vertically integrated companies. They note that while few of the respondents (7.7%) used variable costs in practice, standard cost accounting theory still relies on variable cost pricing. Our approach below utilizes market prices as well as full production costs; in addition we equitably share transaction cost savings that are generated by the vertical integration process.

Regarding the justification of vertical integration, there is a huge literature in the field of industrial organization on why a firm would vertically integrate (Alchian and

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