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Matsui, Kenji

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Cost-based transfer pricing under R&D risk aversion in an integrated supply chain

Kenji Matsui

*Graduate School of Business Administration, Kobe University, 2-1, Rokkodaicho, Nada-ku,
Kobe, Japan*

E-mail address: kmatsui@b.kobe-u.ac.jp

Abstract

This paper examines the economic role of transfer pricing for a vertically integrated supply chain when a risk-averse production-division manager faces uncertainty on the outcomes from R&D investment. In particular, we compare two representative cost-based transfer pricing methods: full-cost and variable-cost pricing. We construct an economic model based on the assumption that R&D investment reduces the expected fixed costs of a production factor as well as the variable production costs. We show that a firm's profit under full-cost transfer pricing is greater than that under variable-cost transfer pricing under certainty. Contrary to this benchmark result, variable-cost pricing becomes more profitable than full-cost pricing when the risk-averse manager bears relatively high risk.

Keywords: transfer pricing; R&D risk aversion; allocation of fixed production costs

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1. Introduction

A number of production economics studies have revealed that the choice of intrafirm transfer pricing method can affect the overall profits of a divisionalized firm and its value through coordination of benefits among multiple internal divisions. A global survey by Ernst & Young (1999) documents that 73% of managers find transfer pricing to be an important factor for maximizing operating performance. Eccles (1985) argues that transfer pricing without regard to "fixed costs, overhead, and profit for the selling division" leads to an unfair "measure of contribution to the company." Assuring some profit to the manufacturing division is particularly important if its manager is to enhance the efficiency of the production process by making discretionary investments. Because division managers are typically evaluated and compensated based on the reported income of their divisions, the method used for setting transfer prices directly influences the decisions delegated to them. For example, corporate headquarters of a divisionalized firm should take into consideration various risks that divisions bear to produce and deal in products. Risk-averse behavior of a division manager may distort internal transfer prices and quantities from levels that are optimal for the whole of the supply chains integrated by the firm.

A survey research paper by Tang (1992) on the transfer pricing methods employed by Fortune 500 firms reports that the "overall profit to the company" is the most important variable that influences the international transfer pricing method. Table 1 illustrates the survey results of Tang (2002) regarding what proportion of the surveyed Fortune 500 or 1000 firms employ each transfer pricing method, showing that the cost-based pricing method is the most prevalent in practice.¹ Of these, 62.8 percent use actual or standard full production costs, 30.8 percent use actual or standard full production costs plus a markup, and only 5.1 percent use variable production costs, indicating that the full-cost transfer pricing method is used more frequently than variable-cost transfer pricing.

¹ Mills (1988) asserts that cost-based methods are the principal basis for determining prices. Based on a survey of the largest 3,500 British companies, he reports that cost-based prices are usually modified by noncost considerations, with competitors' prices being the most important.

[Insert Table 1 here]

Given the transfer pricing practices documented in previous studies, this paper examines the economic role of transfer pricing for a vertically integrated supply chain when a risk-averse production-division manager faces uncertainty regarding the outcomes from R&D investment. Specifically, we investigate the advantages and disadvantages of two representative cost-based transfer pricing methods: full-cost pricing and variable-cost pricing, under uncertainty. We construct an economic model based on the assumption that R&D investment by a production division in a supply chain integrated by a firm reduces the expected overall fixed costs for a production factor as well as the variable production costs.² However, the effectiveness of the R&D investment in reducing fixed costs is assumed to be uncertain. With these settings, we first show that the overall profits of a firm under full-cost transfer pricing is always greater than that under variable-cost transfer pricing when no subordinate divisions face uncertainty. The intuition behind the dominance of the full-cost method is that it induces the production-division manager to invest more in R&D because the manager wishes to reduce production costs when the transfer price includes the fixed cost per unit.

Contrary to the benchmark result without uncertainty, the most important finding from the current research is that variable-cost transfer pricing becomes more profitable from the corporate perspective than full-cost transfer pricing if the risk-averse production-division manager is confronted with greater uncertainty associated with the effectiveness of the investment. The intuition behind this result is summarized as follows. If the manager of the production division adopts risk-averse behavior, the full costing system induces him/her to overinvest compared with the total optimal level for the whole of the supply chain because he/she attempts to avoid variations in the realized fixed cost under uncertainty. Consequently, the production volume becomes greater than the first-best level and the central management

² R&D activities in manufacturing industries are usually classified into two categories: (1) new product development (i.e., research on what to make), and (2) manufacturing technology development (i.e., research on how to make). Note that this paper targets only the latter category of R&D because we focus on the allocation of costs that are reduced through R&D investment.

has to lower the transfer price from the production division to the downstream division to facilitate the greater transfer quantity. Therefore, in such environments, variable-cost pricing imparts to the production division a more appropriate investment incentive than does full-cost pricing. No previous study has documented such an advantage of variable-cost transfer pricing for a firm integrating a supply chain under uncertainty, and this is the primary contribution of this paper.

Our findings give useful insights into supply chain design in multi-echelon corporations. For example, firms should recognize the advantage of the variable-cost transfer pricing method under uncertainty and be cautious about simply implementing full-cost transfer pricing. If the firms' headquarters pass the risk associated with R&D investment to the production-division manager through the full-cost transfer pricing, the internal transfer price is more likely to deviate from the total optimal level. In such environments, variable-cost transfer pricing becomes superior.

Since Hirshleifer (1956) advocated that the internal transfer price be set equal to the marginal cost to alleviate attendant double marginalization problems, subsequent operations research studies have proposed mathematical models that address this problem. Shubik (1962) introduced game theory into cost accounting in the allocation of joint costs at the corporate level. Baumol and Fabian (1964) were the first to employ linear programming to address the transfer pricing problem. Kriens et al. (1983) present industrial problems relating to both management accounting and operations research in divisionalized organizations, including transfer pricing as well as budgeting through input-output analysis and cost-volume-profit analysis. Johansen (1996) investigates the queuing system for the services industry and analyzes how randomness of demand influences optimal transfer pricing. Lantz (2009) focuses on the double marginalization problem arising from the divisionalization and demonstrates that negotiation on transfer price between divisions in a bilateral monopoly setting yields a solution to the problem based on economic experiments.

In the production economics literature, Karmarkar and Pitbladdo (1994) investigate the efficacy of certain cost allocation schemes for common production factors in a competitive environment. They show that, by using the gross contribution as an allocation basis, optimal

product-line decisions are achieved without distorting the selection of production levels. Vidal and Goetschalckx (2001) present a model for optimizing a global supply that maximizes the after-tax profits of a multinational corporation and that includes transfer prices and the allocation of transportation costs as explicit decision variables. They note that, the more restrictive the transfer price determination methods are, the lower is the interest in including decisions on the transfer prices in supply chain models. Villegas and Ouenniche (2008) extend the theory of the multinational firm to the case of multinational supply chains. They establish a model that integrates many factors, such as transport costs and duty drawbacks, which are critical for supply chains that operate under international trade regulations. Rosenthal (2008) studies the problem of setting transfer prices in a vertically integrated supply chain, in which the divisions share technology and transactions costs. He develops a cooperative game that provides transfer prices for the intermediate products in the supply chain, providing a solution that is fair and acceptable to all divisions. Hammami et al. (2008) argue that transfer prices should be considered as an important factor for the design of supply chains in the context of delocalization of organizations.

Moreover, previous management science studies investigate transfer-pricing forms and the ensuing distortions that can affect decentralized firms and demonstrate that prices may differ from marginal costs for a variety of reasons (e.g., Ronen and McKinney, 1970; Harris et al., 1982; Alles and Datar, 1998). Harris et al. (1982) investigate resource allocation through transfer prices in the situation where the productivity of the resource in each division is known only to the division manager. They assume that efforts made by division managers are unobservable by the headquarters, and so divisional productivity cannot be inferred from data on divisional output. Consequently, division managers receive a fixed compensation minus the cost of the resource allocated to them at the chosen transfer price, implying that transfer prices will be below marginal cost. By contrast, Alles and Datar (1998) present a model that explicitly deals with the effects on the strategic decision of setting a transfer price above marginal cost, which supports the frequently used empirical practices of using full production cost plus a markup (Tang, 1992). In their model, transfer prices exceed marginal costs to promote strategic price interactions among firms competing in oligopolistic markets.

The above overview suggests that research comparing cost-based transfer pricing methods for the purpose of supply chain management when a divisional manager bears investment risk under uncertainty is missing in the previous literature in each research strand. Therefore, it is worth analyzing whether the deviation of transfer prices from marginal (variable) cost in an integrated supply chain is favorable under uncertainty, especially from a risk-management viewpoint. This paper aims to address such a practical issue in production economics.

The remainder of this paper is structured as follows. We first delineate the framework and assumptions used for our model in Section 2. In Section 3, we show that full-cost transfer pricing always brings more profit to a firm integrating a supply chain than does variable-cost transfer pricing when the supply chain faces no uncertainty. We introduce uncertainty into the model in Section 4 and demonstrate that variable-cost transfer pricing may surpass full-cost pricing, especially if the division manager is confronted with considerable uncertainty. In Section 5, numerical examples based on a constructed model are presented. We additionally discuss the validity of assumptions and calculation methods in our model in Section 6. Section 7 makes some concluding remarks.

2. Framework and assumptions

Initially, we illustrate the structure of a firm that intends to introduce a cost-based internal transfer pricing system. Consider a firm that produces and distributes a certain product within a supply chain that consists of two echelon divisions: an upper production division and a lower marketing division. The production division produces a certain quantity of the product, and the marketing division subsequently sells this production to end consumers.³ The supply chain uses a production factor that is part of the firm's fixed cost such

³ Wilhelm et al. (2005) describe a case in which parts that are manufactured by a firm are shipped from US plants to border towns and are then cross-docked over the border into Mexico to an assembly plant, and, finally, the finished products are shipped back to the USA for distribution. Such an organization is a typical case of the vertical integration captured in our model.

as technology costs, which is similar to the setting in Karmarkar and Pitbladdo (1994) and Rosenthal (2008). Each of the two diversified divisions is run by a divisional manager employed by the firm's risk-neutral central office ("headquarters"). We assume that decision making regarding R&D investment is delegated to the manager of the production division and that the quantity involved is delegated to the marketing division in the supply chain. The assumption of decentralized decision rights among divisions follows the previous literature (e.g., Alles and Datar, 1998; Sahay, 2003; Shor and Chen, 2009).

A series of events and decisions in the model are presented in the timeline shown in Figure 1. Initially, the CEO in the headquarters announces the transfer pricing policy as being either the full-cost transfer pricing or the variable-cost transfer pricing at date 0. Next, the CEO determines the transfer price of the product from the production division to the marketing division, r , and the amount of subsidy to the production division, s , at date 1. At date 2, the production-division manager of the supply chain chooses the specific R&D investment level, z , which, in turn, reduces the production cost per unit. At date 3, the marketing division manager of the supply chain, after observing the production division's investment decision, determines the number of units of the good, q , that it will buy from the production division. The marketing division sells the good in an external market as the monopolist. Finally, the state of either " H " or " L " proves and uncertainty is removed at date 4. State H represents that the investment made at date 2 proves to be highly effective for the reduction of fixed cost, while State L means that the investment is less effective. On the basis of the realized state, the divisional incomes and the firm's overall profit are computed.⁴

[Insert Figure 1 here]

We use the following series of functions in our model. The inverse demand function of the product is: $p = p(q)$, where p represents the retail price of a unit of the product. For notational simplicity, we hereafter denote the derivative of $p(q)$ by attaching subscript q to

⁴ This timeline indicates that the R&D investment and the fixed cost have the same unit of time. We employ this setting following previous studies that incorporate investment decisions into analytical transfer pricing models (e.g., Holmstrom and Tirole, 1991; Edlin and Reichelstein, 1995; Anctil and Dutta, 1999; Sahay, 2003; Hinss et al., 2005).

the function. Namely, we define: $p_q(q) \equiv dp(q)/dq$ and $p_{qq}(q) \equiv d^2p(q)/dq^2$. Assume that $p_q(q) < 0$ and $p_{qq}(q) \leq 0$ hold. The production division incurs variable production cost $c(z)$, which depends negatively on the investment level, $z (\geq 0)$, undertaken by the division. On the other hand, the fixed cost of the firm depends on the amount of investment undertaken by the production division of the supply chain. We assume that the fixed cost takes each of the following functional forms depending on a realized state, H and L , as: $F_H(z)$, $F_L(z)$, with the probabilities, p_H and p_L , respectively. Therefore, uncertainty is represented by the functional form of the fixed cost, which is not realized until the final date in our model. Because R&D investment is more successful in state H than in state L , then $F_H(z) < F_L(z)$ holds. Additionally, let $F(z)$ denote the expected value of the fixed costs as:

$$F(z) \equiv p_H F_H(z) + p_L F_L(z).$$

We assume that $F_H(z)$, $F_L(z)$ and $c(z)$ are all twice differentiable with respect to each argument, with $F_H'(z) < 0$, $F_H''(z) > 0$, $F_L'(z) < 0$, $F_L''(z) > 0$, $c'(z) < 0$ and $c''(z) > 0$. These inequalities signify that all the costs decline as the investment increases, but that the marginal effect of investment on the costs decreases. Moreover, we assume that $0 > F_H'(z) > F_L'(z)$ and $0 < F_H''(z) < F_L''(z)$, indicating that additional investment in state H leads to less reduction in the fixed costs than that in state L when the total investment amount, z , is given.

Next, we formulate objective functions for each economic agent. Because the risk-neutral CEO of the headquarters attempts to maximize expected overall profit, the CEO's objective function is:

$$\begin{aligned} E\Pi &= \{[p(q) - r]q - s + [r - c(z)]q + s\} - z - F(z) \\ &= [p(q) - c(z)]q - z - F(z) \end{aligned} \quad (1)$$

which is the total revenues from the production division and the marketing division of the supply chain ($p(q)q$) minus variable- and expected fixed-costs ($c(z)q$ and $F(z)$) and costs for R&D investment (z). In advance, we assume that $E\Pi$ is a strictly concave function with

respect to z and q . Not surprisingly, the transfer price, r , disappears from the overall profit function. Secondly, the utility function of the production-division manager differs between the variable costing and the full costing. When the firm implements variable-cost pricing, the expected utility is:

$$Eu_p(\pi_p) = u_p(\pi_p) = u_p([r - c(z)]q - z + s), \quad (2)$$

while the expected utility under full-cost transfer pricing is:

$$Eu_p(\pi_p) = p_H u_p([r - c(z)]q - z - F_H(z) + s) + p_L u_p([r - c(z)]q - z - F_L(z) + s). \quad (3)$$

Equation (3) signifies that the utility under full costing depends on a state realized in the final date. Finally, the functional form of the marketing division manager's expected utility is independent of the firm's costing method as follows:

$$Eu_M(\pi_M) = u_M(\pi_M) = u_M([p(q) - r]q - s). \quad (4)$$

Note that if the expected utility of each division manager were negative, the manager would cease to operate the division. Moreover, if a division posted a net loss, the manager might be accused of losing money, despite the entire corporation earning a profit. Therefore, we consider cross-subsidization to the production division so that the division bears substantial investments and earns positive profits.⁵ Furthermore, we calculate the amount of subsidy (s) that satisfies the "individual rationality (IR) condition", which guarantees positive divisional

⁵ The practice of cross-subsidization within a divisionalized firm is a prominent phenomenon in public utility companies including electricity and telecommunications such as AT&T (Shor and Chen, 2009). The subsidization is also used in other industries ranging from health care (Foreman et al., 1999) and insurance markets (Puelz and Snow, 1994) to professional sports (Fort and Quirk, 1995). See Hughes and Kao (1997) for the relationship between transfer pricing and cross-subsidization.

profits for both the production and marketing divisions.⁶

Because division managers are risk-averse or risk-neutral, we assume that the following inequalities are met:

$$\begin{aligned} u_P'(\pi_P) &> 0, u_P''(\pi_P) \leq 0 \\ u_M'(\pi_M) &> 0, u_M''(\pi_M) \leq 0. \end{aligned} \tag{5}$$

With the above settings, we are ready to solve the optimization problems under each of the two cost-based transfer pricing systems. Table 2 summarizes definitions of the variables and the functions.

[Insert Table 2 here]

3. No uncertainty or the risk-neutral situation

Initially, we investigate solutions in equilibrium under full-cost and variable-cost transfer pricing either when the production division faces no risk regarding the investment, that is, $(p_H, p_L) = (1, 0)$ or $(0, 1)$, or when the production-division manager is risk-neutral, namely, $u_P''(\pi_P) = 0$ even if (p_H, p_L) is neither $(1, 0)$ nor $(0, 1)$. In either situation, the level of investment is not distorted by manager's risk-averse behavior. We first present the total optimal solution of the supply chain as the benchmark. The following lemma would hold if total optimization of the whole of the supply chain were attainable. (All proofs are in the Appendix.)

Lemma 1. Under total optimization of the whole of the supply chain integrated by the firm,

⁶ Economic models that aim to specify desirable contracts closed by multiple agents usually take into account the IR condition of the agents. If incorporating effort level of division managers for the investment into our model, we should also consider the incentive compatibility (IC) condition in addition to the IR condition. See, for example, Salanié (2005) for how the two conditions are practically used. A major example is the description of the principal-agent relationship involving moral hazard and adverse selection problems.

the first-order derivative of the expected overall profit with respect to the amount of investment would be given as follows:

$$TOFOC(z) \equiv \frac{dE\Pi_o}{dz} = p\left(-\frac{1+F'(z)}{c'(z)}\right) - c(z) - \frac{1+F'(z)}{c'(z)} p_q\left(-\frac{1+F'(z)}{c'(z)}\right), \quad (L1)$$

where Π_o and $TOFOC(z)$ represent the profit and the first-order derivative of expected overall maximum profit under total optimization. Hence, the optimal investment level is derived by solving Equation (L1) when it is set equal to zero.

Lemma 1 characterizes the first-best solution for the firm. We, hereafter, investigate the supply chain management problem through transfer pricing, because R&D investment decision-making is delegated to the production division in our model. Compared with the total optimization solution in Lemma 1, optimal investment levels under either of the two cost-based transfer pricing methods are determined as in the next lemma.

Lemma 2. The first-order derivative of the firm's overall profit with respect to the amount of investment under each of the two cost-based transfer pricing systems is given as follows.

(i) Variable costing

$$VCFOC(z) \equiv \frac{dE\Pi_v}{dz} = -F'(z) + \left\{ \left[p\left(-\frac{1}{c'(z)}\right) - c(z) \right] c'(z) - p_q\left(-\frac{1}{c'(z)}\right) \right\} \frac{c''(z)}{[c'(z)]^3}, \quad (L2)$$

(ii) Full costing

$$\begin{aligned} FCFOC(z) &\equiv \frac{dE\Pi_F}{dz} \\ &= \left[-p\left(-\frac{1+F'(z)}{c'(z)}\right) + c(z) + \frac{1+F'(z)}{c'(z)} p_q\left(-\frac{1+F'(z)}{c'(z)}\right) \right] \left\{ -\frac{[1+F'(z)]c''(z)}{c'(z)} + F'''(z) \right\} / c'(z), \end{aligned} \quad (L3)$$

where $VCFOC(z)$ and $FCFOC(z)$ represent the first-order derivatives of expected overall maximum profit under variable costing and full costing, respectively. Similarly, Π_v and Π_F are the profits under the respective costing systems. Therefore, the optimal investment level under each costing system is derived by solving Equation (L2) or (L3) being equal to zero.

To examine the properties of the solutions in the equilibrium, let z_v^* and z_F^* denote the

solutions of the amount of investment under variable costing and full costing based on Equations (L2) and (L3), respectively. Similarly, q_V^* and q_F^* represent the optimal transfer quantities under the respective costing systems. Moreover, as a benchmark solution, let z_O^* and q_O^* represent the first-best investment and transfer quantity under total optimization of the supply chain. Lemmas 1 and 2 yield the following proposition.

Proposition 1. The investment levels in the equilibrium satisfy the following inequality and equality when either the firm faces no uncertainty or the division managers are risk-neutral:

$$z_V^* \neq z_F^* = z_O^* . \quad (\text{P1})$$

Proposition 1 implies that the investment under the variable cost transfer pricing scheme deviates from the first-best level under total optimization of the supply chain while that under full cost transfer pricing is equal to the first-best level. The next corollary follows directly from Proposition 1.

Corollary 1. When the firm either faces no uncertainty or is risk-neutral, the following relationship regarding expected overall profit of the firm under different transfer pricing systems holds:

$$\text{E}\Pi_V^* < \text{E}\Pi_F^* = \text{E}\Pi_O^* , \quad (\text{C1})$$

where $\text{E}\Pi_V^*$, $\text{E}\Pi_F^*$ and $\text{E}\Pi_O^*$ represent the equilibrium profits under variable-cost transfer pricing, full-cost transfer pricing, and total optimization, respectively.

Corollary 1 indicates that the overall profit under variable-cost transfer pricing is less than that under total optimization when the firm operates without uncertainty. Intuitively, full costing induces the production-division manager to have a strong incentive to invest in R&D because it reduces the fixed costs that burden the division. On the other hand, the incentive for R&D investment is weaker for the manager under variable costing, because the manager incurs no fixed costs that are reduced by the investment. Therefore, when R&D investment by the production division reduces not only the variable cost for the division but also the

fixed cost for the entire firm, it is more desirable from the corporate perspective to implement the full-cost transfer pricing method than the variable-cost method. This result in the absence of uncertainty is congruent with empirical evidence in Table 1 by Tang (2002), which suggests that most divisionalized firms use the full production cost plus a markup rather than the variable or marginal cost. The next corollary also follows directly from Proposition 1.

Corollary 2. Endogenous variables and overall profit in equilibrium are the same for the full-cost transfer pricing system and total optimization in the absence of uncertainty.

4. Cost-based transfer pricing system under uncertainty

In this section, we relax previous settings to allow the presence of uncertainty and risk-averse behavior of divisional managers and examine how these conditions alter the previous benchmark results without uncertainty. Because it is highly complicated to solve the functions defined above analytically, we hereafter specify a division manager's utility function as being of constant absolute risk aversion (CARA) form. Let R denote the degree of risk aversion of the production-division manager, $-u_p''(\pi_p)/u_p'(\pi_p)$. With the use of the CARA function, the following proposition holds.

Proposition 2. Only if the production-division manager is risk-averse (i.e., $R > 0$), the full-cost transfer pricing may not attain the expected first-best profit, i.e., $E\Pi_F^* \neq E\Pi_O^*$ in equilibrium. Furthermore, the transfer price under full costing is not set equal to the variable marginal cost excluding fixed costs (i.e., $r \neq c(z)$) only if $R > 0$. Moreover, the firm's overall profit is inversely correlated with R locally if R takes a minimal value.

Proposition 2 proves that the firm can no longer achieve the first-best profit under uncertainty only if $R > 0$, contrary to Corollary 2. As demonstrated in the Appendix, the transfer price is not set equal to the variable marginal cost, $c(z)$ in such circumstances. The

proposition also suggests that the expected overall profit decreases according to R at least locally around 0. If there is a negative correlation between the expected profit and R , not only locally but also globally, the order that full costing is superior to variable costing in Corollary 1 may be reversed under the presence of uncertainty. Hence, if the degree of the production-division manager's risk aversion, R , is sufficiently large, there may exist circumstances where expected profit under full costing becomes smaller than that under variable costing, namely,

$$E\Pi_F^* < E\Pi_V^* < E\Pi_O^*, \quad (6)$$

contrary to Corollary 1 without uncertainty. Figure 2 illustrates this relationship. We confirm that this conjecture actually holds in a numerical simulation in the following section.

[Insert Figure 2 here]

5. Numerical examples

Taking a simulation approach in this section, we present numerical examples where variable-cost transfer pricing generates a larger profit for the firm than full-cost pricing under uncertainty, contrary to Corollary 1 without uncertainty. To conduct a numerical analysis, we specify the functions in our model as follows.

Assumption 1. The functions take the following specific forms:

$$p = a - bq, \quad c(z) = 1/\sqrt{z} + C, \quad u_p(\pi_p) = \alpha - \beta \exp(-R\pi_p), \quad F_H(z) = 1/(k\sqrt{z}), \\ F_L(z) = 1/\{[k/(2k-1)]\sqrt{z}\} \text{ and } p_H = p_L = 1/2,$$

where C represents the fixed part of variable cost that is independent of the investment level such as raw material costs, and α and β are constant and $k \geq 1$.

Assumption 1 includes the CARA function for the production-division manager, which can be derived by solving the differential equation of $-u_p''(\pi_p)/u_p'(\pi_p) = R$. Hence, α and β represent integration constants. Moreover, we employ the linear demand equation, $p = a - bq$,

following previous analytical transfer pricing models mainly for the purpose of facilitating the interpretation of the numerical results (e.g., Karmarkar and Pitbladdo, 1994; Alles and Datar, 1998; Baldenius and Reichelstein, 2006; Shor and Chen, 2009).⁷ Finally, cost functions and probability are set as shown in Assumption 1 because of the following properties. The expected value of the fixed cost, $F(z) \equiv p_H F_H(z) + p_L F_L(z)$, is calculated as:

$$F(z) = 1/\sqrt{z}, \quad (7)$$

which is independent of k . Meanwhile, the variance of the fixed cost is:

$$\text{var}(F(z)) = (k-1)^2 / (k^2 z). \quad (8)$$

Equation (8) indicates that the higher the value of k , the greater the variation in the realized fixed cost F between the two states. These relationships suggest that we may control k as an exogenous parameter of investment risk by preserving the mean (Equation (7)) as a fixed value. Observe that there is no uncertainty associated with the fixed cost only when $k = 1$. Overall, one may confirm that these functional forms satisfy the series of assumptions in previous sections.

With the specifications of the functions, Table 3 displays the solutions of the endogenous variables, (z, q, p, r) , the expected divisional profits, $E\pi_p$ and $E\pi_M$, and the expected overall profit, $E\Pi$, in equilibrium where the exogenous variables are set as:

$(a, b, C, p_H, p_L, k) = (6, 2, 0.1, 1/2, 1/2, 2)$ in Panel A; and

$(a, b, C, p_H, p_L, R) = (6, 2, 0.1, 1/2, 1/2, 5)$ in Panel B.

⁷ Alles and Datar (1998, p.454) construct a benchmark transfer pricing model for oligopolistic firms as follows. When consumers' preferences are uniformly distributed along a segment of a product space like the Hotelling model, a straight-line demand function in Assumption 1 is derived as a result of the optimization behavior of consumers. Accordingly, subsequent management studies that construct analytical transfer pricing models frequently employ the linear demand schedule (e.g., Narayanan and Smith, 2000; Baldenius et al., 2004; Baldenius and Reichelstein, 2006; Shor and Chen, 2009; Matsui, 2011a, 2011c). Following the literature, we employ the linear demand function in our simulation analysis.

See the Appendix on how to calculate the endogenous variables. The degree of risk aversion, R , varies with a given level of uncertainty, k , in Panel A, whereas k varies when R is fixed in Panel B. Subsidy, s , is set as 2.31 so as to satisfy IR conditions, i.e., $E\pi_p > 0$ and $E\pi_M > 0$ for all cases. In both of the panels, the numerical results where variable costing becomes more profitable than full costing are represented by the gray cells, providing significant evidence that the profit from variable costing may exceed that of full costing under several circumstances. For example, Panel A of Table 3 suggests that the variable-cost transfer pricing system generates a larger profit for the firm if the degree of risk aversion by the production manager, R , exceeds 8.637. This numerical result is congruent with our conjecture in the previous section. Next, Panel B of Table 3 documents that the variable costing system becomes more advantageous than full costing when the degree of uncertainty, k , is greater than 3.770. Either when the division manager is risk neutral ($R = 0$ in Panel A) or when there is no uncertainty associated with fixed costs ($k = 1$ in Panel B), the expected profit under full costing is the same as that under total optimization, which is consistent with Corollary 1. The following remark summarizes the basic results of the simulation.

[Insert Table 3 here]

Remark 1. The numerical results from Table 3 suggest that the firm's overall profit under full costing tends to decline under either of the following circumstances: (1) as the degree of risk aversion of the production-division manager, R , increases; and (2) as the degree of uncertainty, k , increases.

Remark 1 suggests that variable costing is more desirable than full costing from the corporate perspective when either: (1) the production-division manager is considerably risk averse; or (2) uncertainty associated with the effectiveness of investment on fixed costs is significant. In summary, the introduction of the variable-cost method enhances the firm's overall profit in such cases, even though the survey result in Table 1 reports that the full production cost method is more frequently used among the cost-based methods.

6. Discussion

6.1 Backward calculation

Given that preceding sections have drawn clear-cut results, this section further discusses the relevance of analytical methods and settings of our model construction. The first issue is the backward induction method for dynamic optimization that we have used. In our model, the CEO optimizes the Lagrangian function to obtain the optimal value of the transfer price in anticipation of the production and marketing managers' optimization behaviors for their division profits. In practice, however, a transfer price may be calculated by either standard or actual costing by referring to past records of variable costs (e.g., raw materials, parts, utility consumption and labor hours) and fixed costs (e.g., machine depreciation, land costs and maintenance) of production. Hence, one might infer that not a backward but a forward calculation method is appropriate in real business processes.

To answer this question, we note that the ultimate goal of the current study is to provide the method to calculate the optimal level of control variables for total profit maximization as the benchmark in a dynamic framework where multiple economic agents independently make decisions, providing practical insights for managers on which transfer pricing method should be applied. If the control variables are not calculated based on the backward induction method but just on a forward method, the variables are not at the optimal level because they do not satisfy "the principle of optimality" in a dynamic optimization algorithm. As a consequence, the derived control variables (e.g., transfer price and supply quantity) do not maximize the total profit for the firm. Hence, from a practical viewpoint, this paper not only provides the optimal transfer price but also sounds the alarm to warn managers in divisionalized firms that just a forward calculation cannot achieve the optimal transfer price that maximizes overall profits.

Moreover, note that our model uses the backward induction method following previous major analytical transfer pricing models that consider a dynamic setting like our model. Such studies include Edlin and Reichelstein (1995), Alles and Datar (1998), Anctil and Dutta (1999), Baldenius et al. (1999), Baldenius (2000), Göx (2000), Narayanan and Smith (2000),

Chwolka and Simons (2003), Sahay (2003), Hinss et al. (2005), Baldenius and Reichelstein (2006), and Pfeiffer et al. (2011).

6.2 Discretionary investment

Second, we discuss the relevance of our assumption that a production manager can make investment decisions without concurrence with the corporation. Because the CEO of the corporation, instead of a subordinate divisional manager, may bear fixed costs in the real business environment, we can alternatively consider the setting where investment is paid not by a manager but by the corporation.

Note that our model assumes that the investment decision is perfectly delegated to the production division manager, primarily because our model deals with uncertainty associated with investment. Specifically, Göx and Schiller (2007) provide a comprehensive review of previous mathematical transfer pricing models that examine the investment aspect, summarizing that models incorporating uncertainty like our model particularly assume that the CEO (or the corporation) of the firm cannot control divisional investment and the investment decision is thus delegated to subordinate division managers. This is because, in the presence of uncertainty, designing a complete contract regarding investment outcomes among the corporation and the divisions that provides specific clauses for all future events is difficult.⁸ For this reason, previous papers that take uncertainty into consideration assume that a division manager can independently make discretionary investments at his/her own risk without concurrence with the corporation. Such studies include Holmstrom and Tirole (1991), Edlin and Reichelstein (1995), Baldenius et al. (1999), Baldenius (2000), Chwolka and Simons (2003), Sahay (2003), Hinss et al. (2005), Baldenius and Reichelstein (2006), and Pfeiffer et al. (2011). Because our model also considers uncertain environments, we follow the above literature to assume that the production division independently makes discretionary investment and bears its costs with the aim of consistency with this line of research.

⁸ In this respect, previous transfer pricing models under uncertainty use insights from

7. Concluding remarks

This paper examined the advantages and disadvantages of two representative cost-based transfer pricing systems—namely, variable-cost transfer pricing and full-cost transfer pricing—for a divisionalized firm. Our model considered a vertically integrated organization that, in general, accrues some technological and transactional cost savings through integration.⁹ When the firm faces no uncertainty or the managers of subordinate divisions are risk-neutral, full-cost transfer pricing always dominates variable-cost transfer pricing from the corporate perspective because the former imparts appropriate incentives for R&D investment to the production division. Contrary to the result under certainty, our major finding is that the variable-cost transfer pricing system dominates the full-cost pricing system when either:

- (1) the production-division manager tends to adopt highly risk-averse behavior; or
- (2) the manager is exposed to a relatively large risk associated with the effectiveness of their R&D investment.

This finding has practical implications for designing supply chain integration in divisionalized organizations. If the firm headquarters inflict R&D risk on the production division through full-cost transfer pricing in industries that are particularly associated with uncertainty, the internal transfer price is more likely to deviate from the total optimization level. In such environments, variable-cost transfer pricing becomes superior, even though previous surveys report that variable-cost transfer pricing is rare in practice (Tang, 1992, 2002). Indeed, Shih (1996) provides empirical evidence that the two-step transfer pricing method is frequently used; namely, both of the two costing methods are separately employed for short-term transfer pricing and long-term transfer pricing. Our results suggest that firms should also use the two methods separately according to the degree of risk with an investment

"incomplete contract theory." For details of this research field, see Salanié (2005).

⁹ When distributing firms that comprise a supply chain are independent from a manufacturing firm, resale price maintenance enables the manufacturer to coordinate the supply chain through controlling wholesale and retail prices under demand uncertainty (Matsui, 2011b).

opportunity. Namely, a firm should use variable-cost transfer pricing for investment associated with relatively high uncertainty, and vice versa. In this respect, we have contributed to the literature by yielding new insights into supply chain management. To summarize, we conclude that managers should only adopt the full-cost transfer pricing system after careful consideration, even though it is frequently practiced by divisionalized companies, especially when one of the supply chain members encounters substantial production risk.

Appendix

Proof of Lemma 1

If the CEO might maximize expected overall profit represented by Equation (1) with respect to (z, q) , following equations would hold:

$$\begin{aligned}\frac{\partial E\Pi}{\partial z} &= -qc'(z) - 1 - F'(z) = 0 \\ \frac{\partial E\Pi}{\partial q} &= p(q) + qp_q(q) - c(z) = 0\end{aligned}\tag{A1}$$

Eliminating quantities, q , from the first-order conditions yields Equation (L1). Moreover, strict concavity of $E\Pi$ ensures that the derived solution from the first-order conditions leads to the maximization of the profit. \square

Proof of Lemma 2

Because the maximization of each manager's utility is equivalent to that of each divisional profit in the absence of uncertainty, we here derive the first-order conditions of profits instead of utility for simplicity.

(i) Variable-costing solution

We work backwards to solve problems under each of the costing systems. At date 3, the marketing division manager of the supply chain maximizes Equation (4), which is the argument of his/her utility, with respect to q , because he/she does not bear uncertainty. The

first-order and second-order conditions are:

$$\begin{aligned}\frac{\partial \pi_M}{\partial q} &= -r + p(q) + qp_q(q) = 0 \\ \frac{\partial^2 \pi_M}{\partial q^2} &= 2p_q(q) + qp_{qq}(q) < 0\end{aligned}\tag{A2}$$

Note that if π_M is negative at the optimal quantity level of q that satisfies Equation (A2), then the marketing division manager stops to sell the product because of his/her negative utility. The CEO has to adjust s in anticipation of this manager behavior.

The production divisional profit is:

$$\pi_P = [r - c(z)]q - z + s.\tag{A3}$$

Because the division manager also does not face uncertainty, maximization of his/her utility is equivalent to maximization of his/her profit. Let L_P denote the Lagrangian for the manager with the constraint of Equation (A2):

$$L_P \equiv \pi_P + \lambda_M [-r + p(q) + qp_q(q)].\tag{A4}$$

Maximization of the production divisional profit on z at date 2 gives:

$$\frac{\partial L_P}{\partial z} = -c'(z)q - 1 = 0.\tag{A5}$$

The second-order condition is negative as follows:

$$\frac{\partial^2 L_P}{\partial z^2} = -c''(z)q < 0.$$

Note that if π_P is negative at the optimal quantity and investment level of q and z that satisfies Equations (A2) and (A5), then the production division manager shuts down the operation. The CEO has to adjust s in anticipation of this manager behavior.

At date 1, the firm's expected overall profit is described as:

$$E\Pi = [p(q) - c(z)]q - z - F(z).\tag{A6}$$

Hence, we further define L_{CEO} as the Lagrangian function for the CEO as follows:

$$L_{CEO} \equiv E\Pi + \lambda_P [-c'(z)q - 1] + \lambda_M [-r + p(q) + qp_q(q)].\tag{A7}$$

We differentiate L_{CEO} with respect to $(z, q, r, \lambda_P, \lambda_M)$ and eliminate $(q, r, \lambda_P, \lambda_M)$ from the derived first-order condition equations. Then, we obtain Equation (L2) in the equilibrium. Because $E\Pi$ is strictly concave, the solution of Equation (L2), when set equal to zero, ensures

the maximization of the Lagrangian. Moreover, the CEO chooses the subsidy, s , so that it satisfies the IR conditions for the production and marketing managers. Namely, the CEO chooses s to the extent that it satisfies both $\pi_p > 0$ and $\pi_M > 0$ hold.

(ii) Full-costing solution

Similar to the variable-costing case, maximization of the marketing division profit gives:

$$\frac{\partial \pi_M}{\partial q} = -r + p(q) + qp_q(q) = 0. \quad (\text{A8})$$

Note that the marketing division manager stops to handle the product if π_M is negative at q that satisfies Equation (A8). The CEO has to determine s in anticipation of this manager behavior.

The expected production division's profit at date 2 is stated as:

$$E\pi_p = [r - c(z)]q - z - F(z) + s. \quad (\text{A9})$$

Because the division manager operates without uncertainty, expected utility maximization is equivalent to expected profit maximization. Hence, let L_p denote the Lagrangian describing the profit maximization with the constraint of Equation (A8):

$$L_p \equiv E\pi_p + \lambda_M [-r + p(q) + qp_q(q)]. \quad (\text{A10})$$

Maximization of L_p with respect to z gives:

$$\frac{\partial L_p}{\partial z} = -1 - qc'(z) - F'(z) = 0. \quad (\text{A11})$$

The second-order condition is negative as follows:

$$\frac{\partial^2 L_p}{\partial z^2} = -qc''(z) - F''(z) < 0. \quad (\text{A12})$$

Note that the production division manager shuts down the operation if $E\pi_p$ is negative at the optimal quantity and investment level of q and z that satisfies Equations (A8) and (A11). The CEO has to adjust s in expectation of this manager behavior.

Given Equation (A11) as the constraint condition, the CEO maximizes overall profit at date 1. We may define the following Lagrangian function for the CEO based on Equation (1):

$$L_{CEO} = E\Pi + \lambda_p [-1 - qc'(z) - F'(z)] + \lambda_M [-r + p(q) + qp_q(q)]. \quad (\text{A13})$$

Deriving the first-order conditions on $(z, q, r, \lambda_p, \lambda_M)$ and removing $(q, r, \lambda_p, \lambda_M)$ from the

simultaneous equations give Equation (L3). Finally, the CEO chooses s to the extent that it satisfies both $E\pi_p > 0$ and $\pi_M > 0$ hold. \square

Proof of Proposition 1

One may immediately confirm that the solution of z for Equation (L3) set equal to zero is equivalent to that for Equation (L1) set equal to zero, indicating that full-cost pricing leads to the same level of the investment as the first-best solution. Furthermore, strict concavity of $E\Pi$ and assumptions on function forms of $F(z)$, $c(z)$, and $p(q)$ ensure that the solution of z for Equation (L2) set equal to zero is unequal to that for Equation (L1) set equal to zero. \square

Proof of Corollary 1

Remember that the transfer price, r , is removed from the firm's expected overall profit function as shown in Equation (1). Therefore, as the investment level deviates from the first-best solution, z_O^* , the profit level maximized by choosing the optimum of another endogenous variable, q , decreases because of the strict concavity of the profit function. Because of Proposition 1, that $z_V^* \neq z_F^* = z_O^*$, it follows that (C1) holds. \square

Proof of Corollary 2

Proposition 1 demonstrates that the amount of investment under full-cost pricing is equal to that under total optimization. Substituting this equilibrium investment into other functions yields the same economic outcome as the first-best solution. \square

Proof of Proposition 2

Because the marketing division bears no risk at date 3, the marketing division manager maximizes divisional profit, represented by Equation (4) on q , irrespective of his/her degree of risk aversion. The first-order condition is:

$$\frac{\partial \pi_M}{\partial q} = -r + p(q) + qp_q(q) = 0. \quad (\text{A14})$$

At date 2, because the production-division manager's utility form is CARA, the certainty equivalent of the utility may be approximated as:

$$CE_p = E(\pi_p) - R \text{var}(\pi_p) / 2, \quad (\text{A15})$$

where $E(\pi_p) = [r - c(z)]q - z - [p_H F_H(z) + p_L F_L(z)] + s$ and $\text{var}(\pi_p) = p_H p_L [F_H(z) - F_L(z)]^2$. Note that maximization of the expected utility is equivalent to maximization of the certainty equivalent indicated by Equation (A15). Therefore, the Lagrangian function for the manager, L_p , with the constraint of Equation (A14) is described as:

$$L_p \equiv CE_p + \lambda_M [-r + p(q) + qp_q(q)]. \quad (\text{A16})$$

Using the Lagrangian function, the production-division manager maximizes the certainty equivalent with respect to z . Observe that Equation (A16) indicates that $\partial L_p / \partial z = \partial CE_p / \partial z$, implying that the constraint in the Lagrangian function does not affect the investment level. Finally, at date 1, we may define the following Lagrangian function for the CEO with the use of Equation (1):

$$L_{CEO} = E\Pi + \lambda_p \frac{\partial CE_p}{\partial z} + \lambda_M [-r + p(q) + qp_q(q)]. \quad (\text{A17})$$

We take the first-order derivatives of L_{CEO} with respect to $(z, q, r, \lambda_p, \lambda_M)$, deriving the solutions of the variables.

Note here that the first-order condition on r is calculated as $\partial L_{CEO} / \partial r = -\lambda_M = 0$, meaning that the maximization problem for the CEO is not influenced by the marketing manager's decision in equilibrium. Given that $\lambda_M = 0$, Equation (A17) implies that $L_{CEO} = E\Pi$ holds only if $\lambda_p = 0$, where the CEO may attain total optimization of the whole supply chain. Namely, the overall profit maximization by the CEO is not subject to the optimization condition for the production-division manager if $\lambda_p = 0$. In summary, the firm may achieve the first-best profit even under full costing only if $\lambda_p = 0$. After some calculations from the first-order conditions, we obtain the result, $\lambda_p = [p(q) + qp_q(q) - c(z)] / c'(z)$. Therefore, when the firm achieves the first-best profit, it follows that:

$$\begin{aligned} \lambda_p &= 0 \\ \Leftrightarrow p(q) + qp_q(q) - c(z) &= 0. \\ \Leftrightarrow r &= c(z) \end{aligned} \quad (\text{A18})$$

Solving the first-order conditions from the Lagrangian function and $r = c(z)$ yields $R = 0$. This in turn means that $r \neq c(z)$ only if the production-division manager is risk averse (i.e., $R > 0$) in the case of full-cost transfer pricing.

Next, we prove that the firm's overall profit is inversely correlated with R if $R > 0$ around 0 locally. The partial derivative of L_{CEO} in Equation (A17) with respect to R is given as:

$$\frac{\partial L_{CEO}}{\partial R} = -\lambda_P p_H p_L [F_H(z) - F_L(z)] [F_H'(z) - F_L'(z)]. \quad (A19)$$

Because the CEO optimizes the Lagrangian function on all the endogenous variables, the envelope theorem indicates that $dL_{CEO}/dR = \partial L_{CEO}/\partial R$. Hence, Equation (A19) suggests that Π is maximized and equal to the first-best expected profit, Π_O^* , when $\lambda_P = 0$, namely, $R = 0$. Therefore, $\Pi_F < \Pi_O$ when $R = \delta$, where δ is a minimal positive constant, implying that $dL_{CEO}/dR < 0$ when $R > 0$ locally around 0. \square

Calculation of the transfer price in numerical examples

We here illustrate how to calculate the value of the optimal transfer price in Section 5 for the (i) variable-costing case and (ii) full-costing case.

(i) Variable-costing case

Profit for the marketing division based on Assumption 1 is:

$$\pi_M = (p - r)q - s = (a - bq - r)q - s. \quad (A20)$$

Maximization of π_M by solving $\partial \pi_M / \partial q = 0$ at date 3 yields:

$$q = (a - r) / (2b). \quad (A21)$$

Because the production division is free from risk in the variable costing case as indicated by Equation (2), we maximize the following production-division profit with respect to z at date 2:

$$\pi_P = [r - c(z)]q - z + s = (r - 1/\sqrt{z} - C)(a - r)/(2b) - z + s. \quad (A22)$$

We obtain the following by solving $\partial \pi_P / \partial z = 0$:

$$z = \sqrt[3]{(a - r)^2 / (2b^2)} / 2. \quad (A23)$$

Finally, using Equations (A20), (A21), (A22), and (A23), we state the firm's expected overall

profit as:

$$\begin{aligned}
E\Pi &= \pi_p + \pi_M - F(z) = \pi_p + \pi_M - 1/\sqrt{z} \\
&= (a-r)\left(r-C-1/\sqrt{z}\right)/(2b) - z + (a-r)^2/(4b) - 1/\sqrt{z} \\
&= \frac{2(a-r)\left(r-C-\sqrt[3]{4b/(a-r)}\right)-\sqrt[3]{4b(a-r)^2}}{4b} + \frac{(a-r)^2}{4b} - \sqrt[3]{\frac{4b}{a-r}}
\end{aligned} \tag{A24}$$

Maximizing Equation (A24) with respect to r by solving $\partial E\Pi/\partial r = 0$ at date 1 yields the function of r dependent on exogenous parameters, a , b , and C , although we do not present the explicit functional form of r because of its complexity. Because $\partial E\Pi/\partial r$ includes r , a , b , and C , it is obvious that the equilibrium transfer price (r) varies with the exogenous parameters (a , b , and C).

(ii) Full-costing case

Solving the dynamic problem backward, we maximize the following profit for the marketing division at date 3:

$$\pi_M = [p(q) - r]q - s.$$

The first-order condition is:

$$\partial \pi_M / \partial q = -r + p(q) + qp_q(q) = 0. \tag{A25}$$

At date 2, the production-division manager maximizes the following expected utility of Equation (3), which is the objective function for the manager:

$$Eu_p(\pi_p) = p_H u_p([r - c(z)]q - z - F_H(z) + s) + p_L u_p([r - c(z)]q - z - F_L(z) + s).$$

Because Assumption 1 indicates that the production-division manager's utility form is CARA, the certainty equivalent of the expected utility may be approximated as:

$$CE_p = E(\pi_p) - R \text{var}(\pi_p) / 2, \tag{A26}$$

where $E(\pi_p) = [r - c(z)]q - z - [p_H F_H(z) + p_L F_L(z)] + s$ and $\text{var}(\pi_p) = p_H p_L [F_H(z) - F_L(z)]^2$.

Maximization of the expected utility is equivalent to maximization of the certainty equivalent indicated by Equation (A26). Hence, the Lagrangian function for the manager, L_p , with the constraint of Equation (A25) is:

$$L_p \equiv CE_p + \lambda_M [-r + p(q) + qp_q(q)]. \tag{A27}$$

Using the Lagrangian function, the production-division manager maximizes the certainty equivalent with respect to z . The optimization condition is:

$$\partial L_P / \partial z = -1 - qc'(z) - [p_H F_H'(z) + p_L F_L'(z)] - R p_H p_L [F_H(z) - F_L(z)] [F_H'(z) - F_L'(z)] = 0. \quad (A28)$$

Finally, we consider the expected total profit maximization by the CEO at date 1. Given the optimization conditions by the production and marketing managers represented by Equations (A25) and (A28), the Lagrangian function is:

$$\begin{aligned} L_{CEO} &\equiv E\Pi + \lambda_P (\partial CE_P / \partial z) + \lambda_M (\partial \pi_M / \partial q) \\ &= [p(q) - c(z)]q - z - F(z) \\ &\quad + \lambda_P \{-1 - qc'(z) - [p_H F_H'(z) + p_L F_L'(z)] - R p_H p_L [F_H(z) - F_L(z)] [F_H'(z) - F_L'(z)]\} \\ &\quad + \lambda_M \{-r + p(q) + qp_q(q)\} \end{aligned} \quad (A29)$$

Maximization of $E\Pi$ can be achieved by solving $\partial L_{CEO} / \partial r = 0$, $\partial L_{CEO} / \partial z = 0$, $\partial L_{CEO} / \partial q = 0$, $\partial L_{CEO} / \partial \lambda_P = 0$, and $\partial L_{CEO} / \partial \lambda_M = 0$. Next, we substitute the functional forms specified in Assumption 1 into these five simultaneous equations. Because there are five endogenous variables (r , z , q , λ_P , and λ_M) included in the five equations, we can derive r by solving the simultaneous equations. Although we do not present the explicit functional form of r because it is extremely complex, r obviously depends on the exogenous parameters used in Assumption 1 (a , b , C , k , and R). Consequently, the numerical results in Table 3 are calculated by substituting specific values for a , b , C , p_H , p_L , k , and R into the equation system. In addition, we derive s which satisfies IR conditions, $E\pi_P > 0$ and $E\pi_M > 0$.

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Table 1 Transfer pricing methods used by major firms

	For Domestic Transfers		For International Transfers	
	Number of Firms	Percent of Total	Number of Firms	Percent of Total
Pricing Methods				
Cost-based transfer prices:				
Standard full production cost	25	16.9	8	6.4
Actual full production cost	24	16.2	9	7.3
Actual or standard full production cost plus a markup	24	16.2	35	28.2
Actual or standard variable cost of production	4	2.7	0	0.0
Other cost-based pricing method	1	0.7	1	0.8
Subtotal for cost-based methods	78	52.7	53	42.7
Market-based transfer prices:				
Market price	27	18.2	23	18.6
Market price less selling expenses	10	6.7	17	13.7
Other market-based pricing methods	2	1.4	4	3.2
Subtotal for market-based methods	39	26.3	44	35.5
Negotiated prices	25	16.9	17	13.7
Other transfer pricing methods	6	4.1	10	8.1
Total-all methods	148	100.0	124	100.0

Source: Tang (2002, p.35)

Note: This table suggests that full production cost methods are more frequently employed for transfer pricing than variable costing methods among the Fortune 500 or 1000 firms surveyed.

Table 2 Notations

p	Price
q	Quantity
z	Amount of R&D investment by the production division
r	Transfer price from the production division to the marketing division
s	subsidy to the production division
Π	Firm's overall profit
R	Degree of risk aversion of the production-division manager
π_p	Profit of production division
π_M	Profit of marketing division
u_p	Utility of a production-division manager
u_M	Utility of a marketing division manager
p_H	Probability that the state H is realized
p_L	Probability that the state L is realized
$F_H(z)$	Fixed cost when the state H is realized
$F_L(z)$	Fixed cost when the state L is realized
$F(z)$	Expected fixed cost $[F(z) \equiv p_H F_H(z) + p_L F_L(z)]$
$c(z)$	Variable production cost other than raw material costs
C	Raw material costs per unit of production
k	Degree of uncertainty
*	Superscript that denotes the equilibrium
Π_F	Profit under full-cost transfer pricing system
Π_V	Profit under variable-cost transfer pricing system
Π_O	First-best profit under total optimization of whole the supply chain
CE_p	Certainty equivalent of the expected profit of the production division

Table 3 Numerical results

Panel A

Results when the degree of risk aversion (R) varies $(a, b, C, p_H, p_L, k, s) = (6, 2, 0.7, 1/2, 1/2, 2, 2.31)$

TP method	R : degree of risk aversion	z : investment	q : quantity	p : retail price	r : transfer price	$c(z)$: variable cost	$E\pi_p$: expected profit for the production division	$E\pi_M$: expected profit for the marketing division	$E\Pi$: expected total profit
Full costing	0 (risk-neutral)	1.026	1.078	3.844	1.687	1.687	0.297	0.015	0.312
	2	1.174	1.081	3.838	1.676	1.623	0.270	0.027	0.298
	5	1.357	1.089	3.823	1.646	1.558	0.190	0.060	0.250
	8.637 ($=R^*$)	1.544	1.097	3.805	1.611	1.505	0.077	0.098	0.176
	9	1.561	1.098	3.804	1.607	1.500	0.066	0.102	0.168
	10	1.607	1.100	3.799	1.599	1.489	0.035	0.112	0.147
	11	1.651	1.102	3.795	1.590	1.478	0.004	0.121	0.125
Variable costing	any	0.676	1.112	3.776	1.552	1.916	1.228	0.164	0.176
Total optimization (first best)	any	1.026	1.078	3.844	–	1.687	–	–	0.312

Note: The panel presents profit and endogenous variables for different degrees of risk aversion of the production divisional head. The cases where variable costing is more profitable than full costing for the firm are represented by the gray cells, suggesting that the variable costing system is more desirable when $R > 8.637$.

Panel B

Results when the degree of uncertainty (k) varies

$(a, b, C, p_H, p_L, R, s) = (6, 2, 0.7, 1/2, 1/2, 4, 2.31)$

TP method	k : uncertainty	z : investment	q : quantity	p : retail price	r : transfer price	$c(z)$: variable cost	$E\pi_p$: expected profit for the production division	$E\pi_M$: expected profit for the marketing division	E Π : expected profit
Full costing	1 (no uncertainty)	1.026	1.078	3.844	1.687	1.687	0.297	0.015	0.312
	2	1.300	1.086	3.828	1.656	1.577	0.219	0.049	0.268
	3	1.469	1.094	3.812	1.625	1.525	0.125	0.083	0.208
	3.770 ($= k^*$)	1.544	1.097	3.805	1.611	1.505	0.077	0.098	0.176
	4	1.561	1.098	3.804	1.607	1.500	0.066	0.102	0.168
	5	1.617	1.101	3.798	1.597	1.486	0.028	0.114	0.141
	6	1.656	1.103	3.795	1.589	1.477	0.001	0.122	0.123
Variable costing	any	0.676	1.112	3.776	1.552	1.916	1.228	0.164	0.176
Total optimization (first best)	any	1.026	1.078	3.844	–	1.687	–	–	0.312

Note: The results where variable costing is more profitable than full costing for the entire firm are represented by the gray cells, indicating that the variable costing system is superior when $k > 3.770$. The panel suggests that the variable-cost method yields higher overall profit than the full-cost method when the production-division manager faces high uncertainty.

Fig. 1. Timeline of events

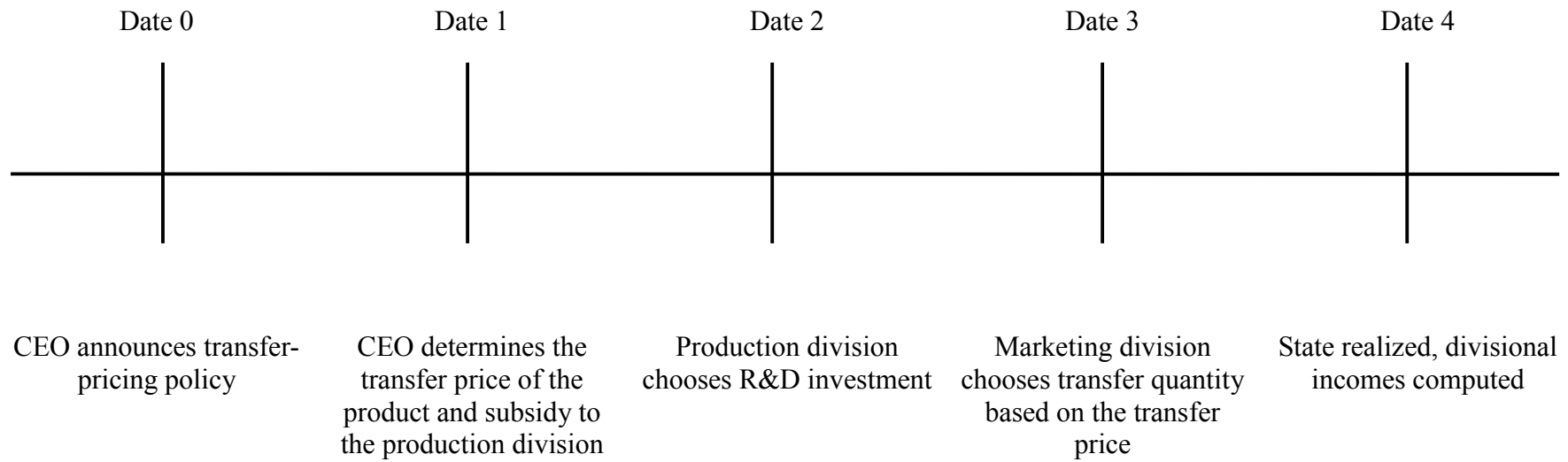
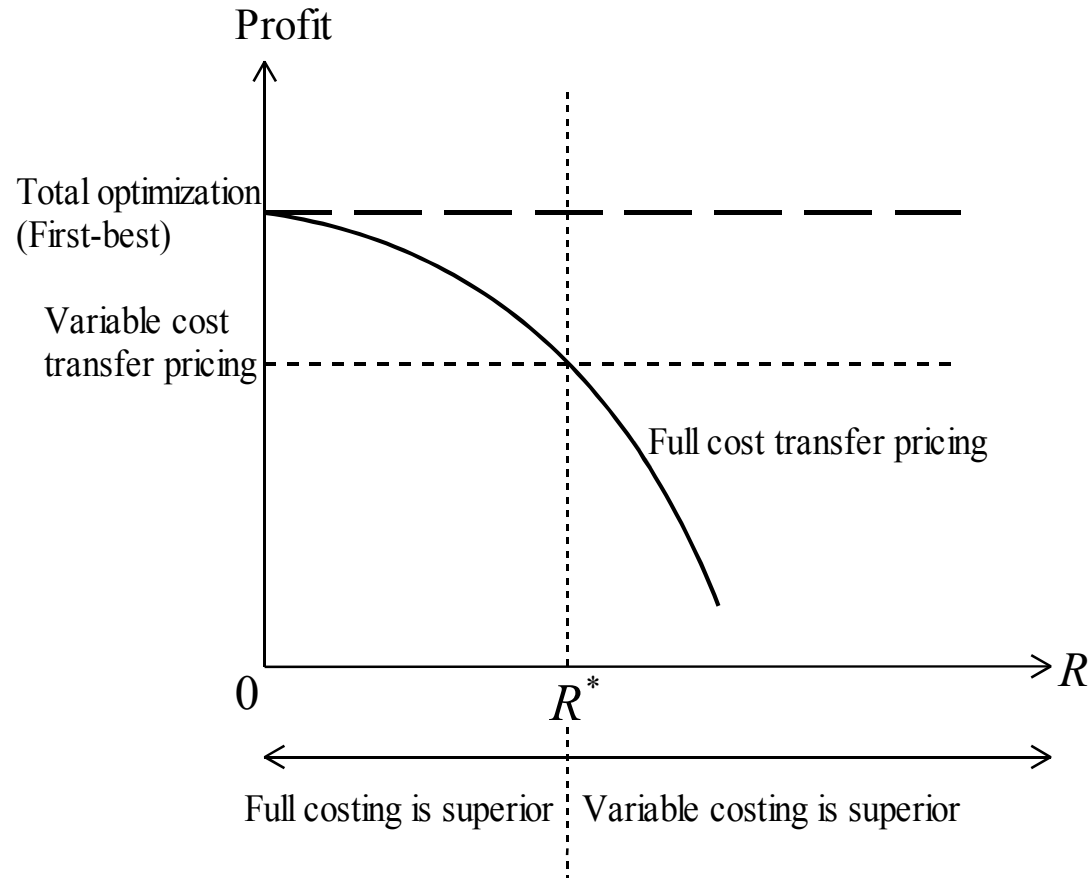


Fig. 2. Comparison of optimized expected overall profit from either costing method under uncertainty



Note: The implications from this figure are: (1) the total optimization outcome is attainable by the full costing system when the production-division manager is risk neutral ($R = 0$), and (2) expected profit under variable costing is greater than that under full costing when R exceeds R^* .