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Negotiated versus Cost-Based Transfer Pricing

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Abstract. This paper studies an incomplete contracting model to compare the effectiveness of alternative transfer pricing mechanisms. Transfer pricing serves the dual purpose of guiding intracompany transfers and providing incentives for upfront investments at the divisional level. When transfer prices are determined through negotiation, divisional managers will have insufficient investment incentives due to "hold-up" problems. While cost-based transfer pricing can avoid such "hold-ups", it does suffer from distortions in intracompany transfers. Our analysis shows that negotiation frequently performs better than a cost-based pricing system, though we identify circumstances under which cost-based transfer pricing emerges as the superior alternative.

Management accounting textbooks and surveys discuss a variety of transfer pricing mechanisms used in practice. While the rules and procedures of these mechanisms have been described extensively in the literature, it seems to be less well understood when particular transfer pricing schemes perform relatively well. Under what circumstances would a firm prefer one particular transfer pricing scheme to another? In this paper, we conduct a performance comparison of two commonly used schemes: negotiated and cost-based transfer pricing. These two alternatives seem particularly prevalent in practice when there is no established external market for the intermediate good in question.[1]

Transfer pricing serves two major purposes in our model: to guide intrafirm transfers of an intermediate product and to create incentives for divisional managers to make relationship-specific investments. Such investments can take different forms, e.g., research and development (R&D), machinery and equipment, or personnel training. In our one-period model, investments entail an upfront fixed cost and a subsequent reduction in the unit variable cost incurred by the supplying division. Alternatively, investments by the buying division may enhance net revenues obtained from internal transactions. The divisional incentive to invest will depend both on the transfer payments and the quantities that the divisions expect to trade.

Earlier literature has shown that negotiated transfer pricing is prone to underinvestment.[2] If the negotiated transfer price splits the total gains from trade available to the two divisions, each division receives only a share of the overall returns to its investments. But if divisions bear the full cost of their investments, a "hold-up" problem will arise such that the resulting investment decisions will be biased downward. The literature on incomplete contracts has shown that this hold-up problem can be mitigated by an initial contractual agreement.[3] However, since formal contracts do not appear to be common in inter-divisional relations, we ignore the possibility of upfront contracts and effectively take the perspective that the intermediate good in question cannot be contractually specified in advance.[4]

In our model of cost-based transfer pricing, the supplying division issues a cost report, and the buying division decides how many units of the good it wants to purchase at that unit cost which then serves as the transfer price. Relying on standard rather than actual cost is necessary since actual unit (variable) cost becomes known only at a later stage, and even then this value will not be verifiable to a central office, e.g., a controller. A common complaint raised in connection with standard-cost transfer pricing is that the supplying division tends to exaggerate its production cost.[5] In the first part of our analysis, we take this possibility to the extreme by assuming that standard cost is based on a cost calculation provided by the selling division, and that outside parties effectively cannot dispute this cost calculation. The selling division then acquires monopoly power: it sets a price and the buying division decides how many units to buy at that price.

We find that negotiated transfer pricing frequently performs better than standard-cost transfer pricing. In settings where only the selling division invests, standard-cost transfer pricing avoids the hold-up problem but entails distortions in the quantities transferred due to the selling division's monopolistic pricing. Generally, these quantity distortions outweigh the positive effect of avoiding the hold-up problem. Only when the buying division's marginal revenue curve is sufficiently concave will the monopoly effect diminish sufficiently so as to give standard-cost transfer pricing an advantage.

Our results are robust to the possibility that the selling division can exaggerate its true (expected) cost only to a limited extent. When the selling division has only limited leeway in inflating its true cost, the resulting quantity distortions become smaller, yet the selling division's investment incentives diminish as well since it receives a smaller share of the overall contribution margin. We find that irrespective of how much leeway there is in issuing the cost report, negotiation will be preferable to cost-based pricing in settings where only the selling division invests.

When only the buying division makes specific investments, cost-based transfer pricing entails a "hold-up" problem of its own: the supplying division will expropriate part of the buyer's investment returns by adjusting its standard-cost report. This effect combined with the quantity distortions inherent in cost-based transfer pricing makes negotiation again the preferred regime when the seller has considerable leeway with its cost report. In contrast, if the selling division is not in a position to issue a standard cost which exaggerates its true expected cost by much, then standard-cost transfer pricing will shift most of the potential contribution margin to the buying division and thereby provide it with appropriate investment incentives. As a consequence, negotiated transfer pricing then becomes the inferior alternative. When both divisions make simultaneous investments, the resulting performance comparison follows the two unilateral investment settings since the investments constitute strategic complements.

The present paper deviates in several respects from recent literature on transfer pricing. We confine our analysis to the relative efficiency of two transfer pricing mechanisms commonly observed in practice. In contrast, most of the recent work on transfer pricing has used the techniques of mechanism design to characterize optimal transfer pricing mechanisms.[6] The mechanisms derived from this approach tend to be "centralized" in the sense that intrafirm transfers and payments are based on reports that divisions make to a central office. For the transfer pricing mechanisms considered in this paper, the central office only specifies generic rules regarding the rights and obligations of the divisions. This is also the approach taken in the earlier work of Baldenius and Reichelstein (1998) who consider a special case of the present model in which the buying division's marginal revenue curve is linear.[7]

Following earlier work on incomplete contracting, we make the assumption that the divisions have imperfect but symmetric information about the relevant state variables. In contrast, informational asymmetries between the divisions have been central to many of the recent models on transfer pricing. Finally, we abstract from moral hazard and managerial compensation issues. Our analysis simply posits that division managers seek to maximize the expected income of their own divisions.[8]

The remainder of this paper is organized as follows. We present the basic model and the two candidate transfer pricing schemes in Section 1. Section 2 compares the performance of these two schemes for settings where, respectively, only the selling division invests, only the buying division invests, or both divisions invest. Section 3 reexamines our comparison results in a setting where the selling division faces constraints on its ability to exaggerate the true expected cost of the intermediate good. Section 4 considers extensions of the model such as two-part transfer pricing schemes. We conclude in Section 5.

1. The Model

Consider a firm that consists of two divisions which operate in separate markets except for an intermediate good that can be transferred inside the firm. We refer to the supplying division as Division 1 (or the seller) and to the buying division as Division 2 (or the buyer). The buyer further processes the intermediate good and sells a final product to the external market. The supplying division can reduce the variable cost of production by undertaking specific investment upfront, for instance, by installing more efficient equipment. The buying division may also invest, e.g., in reducing the cost of further processing the intermediate good or in sales promotions for the final product. The investment decisions have to be made when final costs and revenues are still uncertain. We capture this uncertainty by the random variable θ. The sequence of events is as in Figure 1.

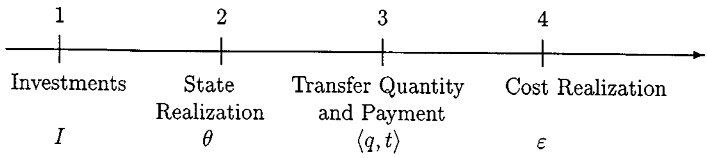

Figure 1. Time line.

At the outset, the central office announces the transfer pricing rules, i.e., either free negotiation or trading at a particular price based on a report by the seller. At date 1, the seller chooses his specific investments I_1 from the interval $[0, \bar{I}_1]$, and similarly, the buyer chooses $I_2 \in [0, \bar{I}_2]$. These investments generate divisional fixed cost of $w_1(I_1)$ for the seller and $w_2(I_2)$ for the buyer.

At date 2, the divisional managers obtain information about revenues and costs. Contingent on the realization of the state variable θ and $I \equiv (I_1, I_2)$, the buying division's net revenue is $R(q, \theta, I_2)$, provided q units of the intermediate product are transferred. For the selling division the anticipated production cost is $\tilde{C}(q, \theta, \tilde{\varepsilon}, I_1) \equiv (c(\theta, I_1) + \tilde{\varepsilon}) \cdot q$. The random variable $\tilde{\varepsilon}$ represents residual cost uncertainty that will not be resolved until the later date 4. Without loss of generality, the mean of $\tilde{\varepsilon}$ is zero, and therefore the expected production cost equals $c(\theta, I_1) \cdot q$. Both division managers know their own valuation of the intermediate good as well as that of the other division.[9]

At date 3, the transfer pricing mechanism determines the actual transfer quantity, $q \in \mathbb{R}_+$, and the transfer payment, $t \in \mathbb{R}_+$, from the buyer to the seller. Neither the state variable θ nor the investments (I_1, I_2) are considered to be verifiable to outside parties such as a central office within the firm. Hence, contingent transfer rules are considered infeasible. Finally, the seller's actual cost is realized at date 4, when ε is realized. It does not matter whether this information becomes known to the buyer, as long as it remains unverifiable.

Specific investments decrease cost and increase net revenue. Throughout our analysis, divisional managers are assumed to be risk-neutral and to maximize their own division's expected income.[10] Risk neutrality implies that at dates 1 and 3 the parties focus on the expected production cost $C(q, \theta, I_1) \equiv c(\theta, I_1) \cdot q$. For given q, I_1, I_2 and θ, the firm's (expected) contribution margin is

$$M(q, \theta, I) \equiv R(q, \theta, I_2) - C(q, \theta, I_1).$$

We assume that $M(\cdot, \theta, I)$ has a unique maximizer, $q^*(\theta, I) > 0$, for all θ, I. Let $M(\theta, I) \equiv M(q^*(\theta, I), \theta, I)$. First-best investments are then given by

$$I^* \equiv (I_1^*, I_2^*) \in \arg\max_I \Pi(I), \tag{1}$$

where $\Pi(I) \equiv E_\theta[M(\theta, I)] - w_1(I_1) - w_2(I_2)$ denotes the expected profit for the firm, given investment levels I_1 and I_2 and efficient trade relative to those investments.

1.1. Negotiated Transfer Pricing

At date 3, the divisional managers bargain over the quantity to be traded and the transfer payment to be paid by the buyer. These negotiations take place under symmetric information about net revenues and production cost. Following earlier literature, we represent the bargaining process by a surplus-sharing rule in which the seller receives a share $\gamma \in [0, 1]$ of the achievable contribution margin. Thus, the parties agree on the quantity $q^*(\theta, I)$ and on a transfer payment, t, given by the equations:

$$t - C(q^*(\theta, I), \theta, I_1) \;=\; \gamma \cdot M(\theta, I) \tag{2}$$

$$R(q^*(\theta, I), \theta, I_2) - t \;=\; (1 - \gamma) \cdot M(\theta, I). \tag{3}$$

We consider γ as an exogenous parameter representing the seller's bargaining power, with $\gamma = \frac{1}{2}$ representing the Nash bargaining solution.[11] Negotiated transfer pricing will suffer from underinvestment since, according to (2) and (3), each of the divisions receives only a share of the additional surplus generated by its investments. At the same time, each division bears the full cost of its investment.

1.2. Cost-Based Transfer Pricing

Under this scheme, the seller quotes a unit cost, v^s, and the buyer can choose the quantity to be traded at this transfer price. If the unit cost, $c(\theta, I_1)$, is unverifiable to other parties, the selling division will effectively have monopoly power. Though in practice the selling division will be limited in its ability to overstate its cost, our analysis will ignore such constraints in Section 2 below. Our model formulation then captures the most common criticism of standard cost transfer pricing: standards are determined largely by a party that has a vested interest in biasing the standard. The selling division anticipates that for any standard cost, v^s, the buyer orders a quantity $q(v^s, \theta, I_2) \in \arg\max_q \{R(q, \theta, I_2) - v^s \cdot q\}$, where $q(\cdot)$ is the inverse of the buyer's marginal revenue curve. Thus, the seller quotes a unit cost $v^s(\theta, I)$ satisfying

$$v^s(\theta, I) \in \arg\max_v \{[v - c(\theta, I_1)] \cdot q(v, \theta_2, I_2)\}.$$

The transfer payment then amounts to $t = v^s(\theta, I) \cdot q^s(v^s(\theta, I), \theta, I_2)$.

Since $v^s(\theta, I)$ will exceed the unit cost $c(\theta, I)$, this scheme suffers from the well-known "double marginalization of rents," i.e., $q^s(\theta, I) \equiv q(v^s(\theta, I), \theta, I_2) \leq q^*(\theta, I)$. Because investment incentives depend on the expected trading quantity, the resulting investment decisions will also be suboptimal under this scheme. Finally, we note that the buying division retains some bargaining power under standard-cost transfer pricing since the selling division is restricted to charge a uniform price.

2. Unconstrained Cost Reporting

2.1. Supplier Investment

We first disregard the possibility of investments by the buying division. Thus $I_2 \equiv 0$, and we denote $R(q, \theta, I_2 = 0) \equiv r(q, \theta)$. For any investment by the supplying division, I_1, the maximum expected firm profit is given by $\Pi(I_1) = M(\theta, I_1) - w_1(I_1)$. We employ the following assumptions:

(A1) For all θ: $\partial c(\theta, I_1)/\partial I_1 < 0$, and $c(\theta, \bar{I}_1) \geq 0$.

(A2) $\Pi(I_1)$ is single-peaked in I_1 with an interior optimum I_1^*.

Since $M(\theta, I_1) \equiv M(q^*(\theta, I_1), \theta, I_1)$, the Envelope Theorem yields the following first-order condition for the maximum:

$$w_1'(I_1^*) = -E_\theta \left[\frac{\partial c(\theta, I_1^*)}{\partial I_1} \cdot q^*(\theta, I_1^*) \right]. \tag{4}$$

Hence, the selling division should invest up to the point where the expected marginal cost savings are equal to the marginal investment cost.

We assess the relative performance of the two transfer pricing mechanisms by comparing the expected firm-wide profits resulting under each scheme. Since negotiated transfer pricing leads to ex-post efficient trading quantities while cost-based pricing does not, one would expect that a standard-cost scheme will perform better only if it induces larger investments by the seller. This is indeed true subject to the regularity condition stated in (A2). Let I_1^n and I_1^s denotes the investments induced by negotiated and cost-based transfer pricing, respectively.

Lemma 1 *Given (A2), a necessary condition for cost-based transfer pricing to dominate negotiated transfer pricing is that* $I_1^s > I_1^n$.

As argued above, the return on investment is essentially determined by the expected production quantity.[12] Under the cost-based regime, the traded quantity q^s is less than the efficient quantity q^*, which results under negotiations. On the other hand, a negotiated transfer pricing scheme entitles the supplying division only to a γ-share of the surplus available at date 3. The seller then solves the following problem:

$$I_1^n \in \arg\max_{I_1} \{\gamma \cdot E_\theta[M(\theta, I_1)] - w_1(I_1)\},$$

which, by the Envelope Theorem, yields the necessary first-order condition:

$$w_1'(I_1^n) = -\gamma \cdot E_\theta \left[\frac{\partial c(\theta, I_1^n)}{\partial I_1} \cdot q^*(\theta, I_1^n) \right]. \tag{5}$$

Under cost-based transfer pricing, the seller solves

$$I_1^s \in \arg\max_{I_1} \{E_\theta[v^s(\theta, I_1) \cdot q(v^s(\theta, I_1), \theta) - C(q(v^s(\theta, I_1), \theta), \theta, I_1)] - w_1(I_1)\},$$

which, upon differentiation, leads to

$$w_1'(I_1^s) = -E_\theta \left[\frac{\partial c(\theta, I_1^s)}{\partial I_1} \cdot q^s(\theta, I_1^s) \right]. \tag{6}$$

Investment incentives under both schemes are driven by the increase in expected contribution margin accruing to the seller. This depends on both the expected production cost savings and the seller's bargaining power as represented by the parameter γ.

The following result shows that the relative loss in trading volume under cost-based transfer pricing depends on the curvature of the buying division's marginal revenue function.

Lemma 2 *Under cost-based transfer pricing,*

$$q^s(\theta, I) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \frac{1}{2} q^*(\theta, I) \quad \text{if} \quad r'(q, \theta) \text{ is } \begin{Bmatrix} \text{concave} \\ \text{linear} \\ \text{convex} \end{Bmatrix} \text{ in } q.$$

The buyer's marginal (net) revenue curve $r'(q, \theta)$ is the selling division's inverse demand function for the intermediate good. The curvature of this function determines the extent of the trade distortions. In particular, internal trade will be distorted more severely if the marginal revenue curve is convex.

When the seller's bargaining power equals $\gamma = \frac{1}{2}$, we are now in a position to compare the investments resulting under the two regimes.

Lemma 3 *Suppose (A1) holds and only the supplying division invests. If* $\gamma = \frac{1}{2}$,

$$I_1^n - I_1^s \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0 \quad \text{if} \quad r'(q, \theta) \text{ is } \begin{Bmatrix} \text{concave} \\ \text{linear} \\ \text{convex} \end{Bmatrix} \text{ in } q.$$

We note that, if $r'(q, \theta)$ is linear, then $q^s(\cdot) = \frac{1}{2} \cdot q^*(\cdot)$. If $\gamma = \frac{1}{2}$ (Nash bargaining solution), we find that $I_1^n = I_1^s$ since the hold-up effect and the trade distortion effect cancel each other precisely. Under cost-based transfer pricing, the supplying division is residual claimant to all cost savings, but these savings apply only to half the efficient quantity.

Clearly, the inequality $I_1^n \geq I_1^s$ will hold for any $\gamma > \frac{1}{2}$, provided $r'(q, \theta)$ is convex. This observation immediately gives rise to the main result of this subsection.

Proposition 1 *Suppose only the supplier invests, (A1) and (A2) hold, and* $r'(q, \theta)$ *is convex in* q. *Negotiated transfer pricing then dominates cost-based transfer pricing provided* $\gamma \in [\frac{1}{2}, 1]$.

Proposition 1 generalizes our earlier results in Baldenius and Reichelstein (1998). The analysis in that paper confined attention to the case of linear marginal revenue curves. Consider next a setting where, contrary to the hypothesis in Proposition 1, $r'(q, \theta)$ is strictly concave and $\gamma \leq \frac{1}{2}$. According to Lemma 3, we have $I_1^n < I_1^s$. As a consequence, the firm faces a trade-off between improved investment under standard cost transfer pricing and the associated trading loss. The following example shows that, for particular functional forms of $r'(q, \theta)$, this tradeoff may favor the cost-based mechanism.

Example: Suppose $\gamma = \frac{1}{2}$ and the inverse demand function for the final product is given by $P(q, \theta) = a(\theta) - b \cdot q^\nu$, $\nu > 1$. The buying division's demand function for the intermediate good is then given by

$$r'(q, \theta) = a(\theta) - (\nu + 1) \cdot b \cdot q^\nu,$$

where $a(\theta) > c(\theta, I_1)$, for all θ, I_1 and $b > 0$. The marginal revenue function, $r'(q, \theta)$, is concave in q if and only if $P(q, \theta)$ is concave in q which, in turn, is equivalent to $\nu \geq 1$.[13]

For given I_1, the quantities traded under the two regimes are

$$q^*(\theta, I_1) = \left(\frac{a(\theta) - c(\theta, I_1)}{(\nu + 1) \cdot b}\right)^{1/\nu}$$

under negotiations, and

$$q^s(\theta, I_1) = \left(\frac{a(\theta) - c(\theta, I_1)}{(\nu + 1)^2 \cdot b}\right)^{1/\nu}$$

under standard cost transfer pricing. We note that for all $\nu > 1$, $q^*(\cdot) < 2 \cdot q^s(\cdot)$.

Suppose now that the internal demand becomes sufficiently concave, i.e., ν gets sufficiently large. Then the trade distortion is negligible, as $\lim_{\nu\to\infty} q^s(\cdot) = \lim_{\nu\to\infty} q^*(\cdot) > 0$. Ultimately, the investment effect dominates so that $\Pi^s > \Pi^n$. ■

In summary, the intuition that a cost-based transfer pricing scheme may avoid the hold-up problem associated with negotiated transfer pricing is correct. At the same time, however, investment incentives are driven by the expected production quantity. The monopoly effect inherent in the cost-based transfer pricing scheme generates the necessary condition that marginal revenues be concave in order for $I_1^s > I_1^n$. Even if this condition is met, however, negotiated transfer pricing still has the advantage of more efficient internal transfers. In order for cost-based transfer pricing to overcome this disadvantage, the function $r'(q, \theta)$ will have to be sufficiently concave.

2.2. Buyer Investment

We now consider the complementary case where only investments by the buyer are of importance. Thus, $I_1 \equiv 0$, and we denote $c(\theta, I_1 = 0) \equiv c(\theta)$. One might suspect that cost-based transfer pricing is even less effective now since it tends to give the seller more bargaining power compared with a negotiation regime, at least relative to $\gamma = \frac{1}{2}$. The following assumptions are analogous to (A1) and (A2) for the case of buyer investments:

(A3) $R(q, \theta, I_2) = r(q, \theta) + I_2 \cdot q$.

(A4) The function $\Pi(I_2) \equiv M(\theta, I_2) - w_2(I_2)$ is single-peaked in I_2 with an interior optimum I_2^*.

For technical reasons, we shall also assume that $\bar{I}_2 \leq c(\theta)$ for all θ. The unique level of first-best investments, I_2^*, is characterized by

$$w'(I_2^*) = E_\theta[q^*(\theta, I_2^*)], \tag{7}$$

since by (A3) the marginal benefit of investment is equal to the expected trading quantity. Negotiated transfer pricing experiences the same problems as in the seller investment setting considered above. The buying division underinvests because it appropriates only part of the additional surplus generated by its investments. The first-order condition characterizing the buyer's investment choice is

$$w_2'(I_2^n) = (1-\gamma)\cdot E_\theta[q^*(\theta, I_2^n)]. \tag{8}$$

Under cost-based transfer pricing, the buying division anticipates that the seller tends to raise the quoted standard cost provided the buyer's valuation for the intermediate good is increased through his investments. The buying division's investment problem can be written as

$$\begin{aligned} I_2^s \;\in\; \arg\max_{I_2}\{E_\theta[R(q(v^s(\theta, I_2), \theta, I_2), \theta, I_2) \\ - v^s(\theta, I_2)\cdot q(v^s(\theta, I_2), \theta, I_2)] - w_2(I_2)\}. \end{aligned}$$

Differentiating with respect to I_2 yields

$$w_2'(I_2^s) = E_\theta\left[\left(1 - \frac{\partial v^s(\theta, I_2^s)}{\partial I_2}\right)\cdot q^s(\theta, I_2^s)\right]. \tag{9}$$

Equation (9) exhibits an additional "hold-up" effect inherent in the buyer investment scenario under cost-based transfer pricing.

However, the price charged by the selling division, $v^s(\theta, I_2)$, need not always be increasing in I_2. For instance, if the internal demand curve exhibits constant elasticity, then the optimal monopoly price is decreasing in positive demand shifts, i.e., $\partial v^s(\cdot)/\partial I_2 < 0$. However, it turns out that $\partial v^s(\cdot)/\partial I_2 \geq \frac{1}{2}$, if $r'(q, \theta)$ is concave in q. Furthermore, $\partial v^s(\cdot)/\partial I_2 \geq 0$, if $r'(q, \theta)$ is log-concave in q.[14] These observations suggest a strong case for negotiated transfer pricing when investments by the buyer are important.

Proposition 2 *Suppose only the buyer invests, and (A3)–(A4) hold. Provided $\gamma \in [0, \frac{1}{2}]$, negotiated transfer pricing dominates cost-based transfer pricing if either one of the following two conditions holds:*

(i) $r'(q, \theta)$ is concave in q, or

(ii) $r'(q, \theta)$ is convex and log-concave in q.

We note that a convex function is log-concave provided its second derivative is sufficiently small. The conditions identified in Proposition 2 imply that $I_2^n \geq I_2^s$. To demonstrate this, we may rewrite (9) in the following way:

$$w'(I_2^s) = E_\theta[\mu(\theta, I_2^s)\cdot q^*(\theta, I_2^s)], \tag{10}$$

where

$$\mu(\theta, I_2) \equiv \left(1 - \frac{\partial v^s(\theta, I_2)}{\partial I_2}\right)\cdot \frac{q^s(\theta, I_2)}{q^*(\theta, I_2)}$$

is an auxiliary function that allows us to express the buyer's marginal investment return in terms of the efficient quantity $q^*(\cdot)$.

A sufficient condition for $I_2^s \leq I_2^n$ is that $\mu(\theta, I_2) \leq (1-\gamma)$, for all θ, I_2. If $r'(\cdot,\theta)$ is concave in q, then, as described above, we find that $\partial v^s/\partial I_2 \geq \frac{1}{2}$. At the same time, $q^s(\cdot) < q^*(\cdot)$, yielding $\mu(\theta, I_2) < \frac{1}{2}$, for all θ, I_2. To illustrate condition (ii) in Proposition 2, we find that $\partial v^s/\partial I_2 \geq 0$ if $r'(\cdot,\theta)$ is log-concave in q. Furthermore, Lemma 2 shows that $q^s(\cdot) \leq \frac{1}{2}q^*(\cdot)$, provided $r'(\cdot,\theta)$ is convex. It then follows again that $\mu(\theta, I_2) \leq \frac{1}{2}$. In both cases, marginal investment returns are uniformly greater under negotiated transfer pricing, provided $\gamma \leq \frac{1}{2}$.

When $r'(q,\theta)$ is linear, the deficiency of cost-based transfer pricing is particularly apparent. We recall that if only the supplying division invests, then $I_1^n \geq I_1^s$, provided $\gamma \in [\frac{1}{2}, 1]$. If the buyer undertakes investments, then this dominance range is even larger: $I_2^n \geq I_2^s$, provided $\gamma \in [0, \frac{3}{4}]$. To see this, note that if $r'(q,\theta)$ is linear in q, then the transfer price, $v^s(\theta, I_2)$, will increase at a rate of one half in the investment I_2. Thus $\mu(\theta, I_2) \equiv \frac{1}{4}$, and the marginal returns from investing are given by $\frac{1}{4}E_\theta[q^*(\theta, I_2)]$. This is less than the corresponding return under negotiated transfer pricing which equals $(1-\gamma)E_\theta[q^*(\theta, I_2)]$ for all $\gamma \leq \frac{3}{4}$.

2.3. Bilateral Investments

We finally consider a setting where both divisions may undertake simultaneous investments. To assess the relative performance of the transfer pricing schemes, we focus on Nash equilibria of the induced investment games. Our analysis invokes the following assumptions which generalize similar ones used in the previous sections.

(A5) $R(q,\theta,I_2) = r(q,\theta) + I_2 \cdot q$, and $C(q,\theta,I_1) = [c(\theta) - I_1]\cdot q$.

(A6) $\Pi(I_1, I_2)$ has a unique interior maximizer $I^* \equiv (I_1^*, I_2^*)$. For any fixed value I_i, $\Pi(I_i, \cdot)$ is concave in I_j on the interval $[0, I_j^*]$, for $i, j = 1, 2, i \neq j$.

(A7) $w_i'(0) = 0$, for $i = 1, 2$.

Assumption (A5) says that investments have a constant marginal effect. (A6) will be technically helpful to ensure existence and uniqueness of Nash equilibria, while (A7) ensures that Division i invests a positive amount even if $I_j = 0, i \neq j$. Again, we shall also impose the technical restriction that $\bar{I}_2 \leq c(\theta) - \bar{I}_1$ for all θ.

The interdependence of the investment decisions can be easily illustrated for negotiated transfer pricing. As argued in connection with (5) and (8), the divisions' investment incentives depend on the expected trading quantity. This quantity is increasing in the investments of each division. As a consequence, the reaction curves will have positive slopes.[15] A pure strategy Nash equilibrium under negotiated transfer pricing is characterized by the following simultaneous equations:

$$w_1'(I_1^n) = \gamma E_\theta[q^*(\theta, I_1^n, I_2^n)] \quad \text{and} \quad w_2'(I_2^n) = (1-\gamma)E_\theta[q^*(\theta, I_1^n, I_2^n)], \quad (11)$$

where $q^*(\cdot)$ solves the equation: $r'(q^*(\cdot), \theta) + I_2 - c(\theta) + I_1 = 0$.

Lemma 4 *Given that (A5)–(A7) hold, there exists a unique Nash equilibrium under negotiated transfer pricing with $I_1^n < I_1^*$ and $I_2^n < I_2^*$.*

The equilibrium analysis is more complicated under cost-based transfer pricing. Since the additional hold-up term $\partial v^s(\theta, I)/\partial I_2$ is itself a function of I_2, non-concavities in the buyer's objective function may arise. As a consequence, the reaction functions may no longer be well-behaved. To ensure existence of a Nash equilibrium in mixed strategies, we assume that division managers choose their investments from the finite sets $\mathbf{I_1} \equiv \{0, I_1^1, \ldots, I_1^m = \bar{I}_1\}$ and $\mathbf{I_2} \equiv \{0, I_2^1, \ldots, I_2^{\tilde{m}} = \bar{I}_2\}$. It will be convenient to choose these sets in such a way that the equilibrium investments under negotiated transfer pricing, (I_1^n, I_2^n), belong to $\mathbf{I_1} \times \mathbf{I_2}$.

In the following result, we essentially invoke the "intersection" of the conditions used in the unilateral investment scenarios, which allows us to obtain the corresponding result for bilateral investments.

Proposition 3 *Suppose (A5)–(A7) hold and $\gamma = \frac{1}{2}$. The negotiated transfer pricing dominates cost-based transfer pricing if $r'(q, \theta)$ is convex and log-concave in q.*

The proof of Proposition 3 shows that any investment pair (I_1^s, I_2^s), which is played with positive probability in any mixed strategy equilibrium under cost-based transfer pricing, must satisfy the inequality $(I_1^s, I_2^s) \leq (I_1^n, I_2^n)$. This is essentially a consequence of the strategic complementarity of the investments combined with our earlier characterizations obtained in the unilateral cases.

To illustrate, we focus on the special case where $\gamma = \frac{1}{2}$ and $r'(q, \theta)$ is linear in q. From the discussion of the unilateral investment cases, we then know that $I_1^n(I_2) \equiv I_1^s(I_2)$ while $I_2^n(I_1) > I_2^s(I_1)$, for all I_1. This case is depicted in Figure 2.

While Proposition 3 requires $\gamma = \frac{1}{2}$, we now show that the above result holds for a wider range of γ-values provided the marginal revenue curve is linear and investment costs are quadratic.

Corollary to Proposition 3 *Suppose (A5) and (A6) hold, $r'(q, \theta)$ is linear and both divisions' investment cost functions are given by $w_1(x) = w_2(x) = \frac{\beta}{2}x^2$. Then negotiated transfer pricing strictly dominates cost-based transfer pricing for all $\gamma \in [\frac{1}{4}, \frac{3}{4}]$.*

If the investment costs are quadratic and symmetric, then *total* investments under negotiated transfer pricing, $I_1^n(\gamma) + I_2^n(\gamma)$, are independent of γ, since $dI_1^n/d\gamma = -dI_2^n/d\gamma$. Thus, the parameter γ impacts expected profits only through the sum of the investment costs. These costs are a convex function of γ and symmetric around $\gamma = \frac{1}{2}$. Given the linearity of $r'(q, \theta)$, we know from Proposition 1 that $I_1^n(I_2) \geq I_1^s(I_2)$, for all I_2 and all $\gamma \geq \frac{1}{2}$. At the same time, Proposition 2 implies that $I_2^n(I_1) \geq I_2^s(I_1)$, for all I_1 and all $\gamma \leq \frac{3}{4}$. Strategic complementarity yields $I^n \geq I^s$ for all $\gamma \in [\frac{1}{2}, \frac{3}{4}]$ and thus

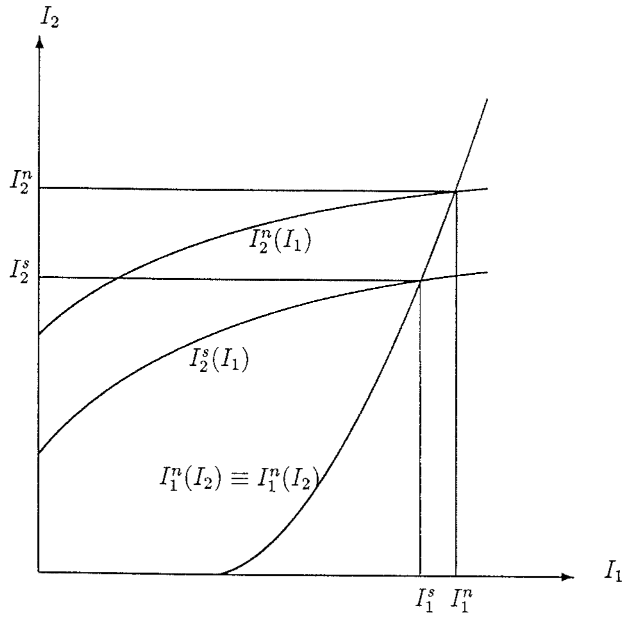

Figure 2. Investment equilibrium with linear marginal revenue curve and $\gamma = 1/2$.

$\Pi^n(\gamma) \geq \Pi^s$ within that range. The result then follows from the symmetry of $\Pi^n(\gamma)$ around $\gamma = \frac{1}{2}$.

3. Constrained Cost Reporting

The above analysis has assumed that the selling division faces no constraints on the cost report it issues under cost-based transfer pricing. As argued in the Introduction, this assumption will be descriptive only in settings where third parties, such as a controller, do not have sufficient information to dispute the validity of the cost calculation supplied by the selling division.

In this section, we introduce explicit constraints on the seller's standard-cost report. Specifically, we assume that a controller would dispute the selling division's reported cost $v^s(\theta, I)$, whenever $v^s(\theta, I) > c(\theta, I_1) + \Delta^*$, where $\Delta^* \geq 0$ can be interpreted as measurement error.[16] While the firm may generally incur additional monitoring costs in order to achieve lower values of Δ^*, we will not model this choice but instead treat Δ^* as a given, exogenous, parameter. If only the seller invests, the standard-cost report is given by:

$$v^s(\theta, I_1, \Delta^*) \in \arg\max_v \{(v - c(\theta, I_1)) \cdot q(v, \theta)\}$$
$$\text{subject to: } v \leq c(\theta, I_1) + \Delta^*. \tag{12}$$

When the selling division faces no constraints on the choice of v, there is clearly no purpose in granting the supplying division a mark-up on its self-reported standard cost. When the seller's cost is partially verifiable, however, such mark-ups may become desirable.[17] Let Δ^{**} be a constant mark-up per unit of output on standard cost. The resulting transfer price then becomes $t = (v + \Delta^{**}) \cdot q$. Provided the selling division has discretion to charge less than the allowable mark-up Δ^{**}, it is readily seen that the supplying division's optimization problem is precisely that in (12) except that Δ^* is replaced by $\Delta \equiv \Delta^* + \Delta^{**}$. In particular, $v^s(\theta, I, \Delta)$ denotes the seller's reported standard cost when the reported figure can exceed true cost by at most Δ^*, the allowable mark-up is at most Δ^{**}, and $\Delta = \Delta^* + \Delta^{**}$. For values of Δ sufficiently large, the joint reporting and mark-up constraint will not be binding, and the standard-cost transfer pricing will perform as shown in Section 2.

For small values of Δ, however, both investment and intrafirm trade under cost-based transfer pricing will differ from those derived above. We first consider the setting in which only the supplier makes specific investments. For Δ sufficiently small, the resulting transfer price will be equal to $c(\theta, I_1) + \Delta$, and therefore the seller's investment satisfies

$$I_1^s(\Delta) \in \arg\max_{I_1}\{E_\theta[\Delta \cdot q(v^s(\theta, I_1, \Delta), \theta)] - w_1(I_1)\}. \tag{13}$$

For $\Delta = 0$, the intrafirm transfers would be ex-post efficient, since the buyer would be charged actual marginal cost. Yet, the supplying division would lose all incentives to invest, since it would not earn any contribution margin. As a consequence, $I_1^s(0) = 0$.

In light of Proposition 1, we conclude that negotiated transfer pricing dominates cost-based transfer pricing for values of Δ either sufficiently large or sufficiently small. The following result shows that this ordering also holds for intermediate values of Δ provided the buying division's marginal revenue curve is linear.

Proposition 4 *Suppose only the supplier invests, (A2) holds, $c(\theta, I_1) = c(\theta) - I_1$, and $r'(q, \theta)$ is linear in q. For all values of Δ, negotiated transfer pricing dominates cost-based transfer pricing, provided $\gamma \in [\frac{1}{2}, 1]$.*

The proof of this result follows the reasoning given in Proposition 1. Since the quantities traded are always efficient under negotiated transfer pricing, it suffices to show that the resulting specific investment is higher under negotiated transfer pricing than under cost-based transfer pricing. Under negotiation, the marginal return of investment is $\gamma \cdot E[q^*(\theta, I_1)]$. The proof of Proposition 4 establishes that with a linear demand curve the marginal return on investment under standard-cost transfer pricing is less than $\frac{1}{2} \cdot q^*(\theta, I_1)$ for any Δ. The result then follows, provided the seller's bargaining power, γ, is at least one-half. It remains an open question whether the result in Proposition 1 can be extended to the entire class of convex marginal curves considered in Proposition 1.

In situations where only the buying division invests, the performance of standard-costing will be improved significantly by partial verifiability of the seller's unit cost. In particular for $\Delta = 0$, we notice that cost-based transfer pricing achieves first-best results. Intrafirm transfers will be priced at the seller's unit variable cost, and since the entire gains from trade accrue to the buying division, it follows that this division will invest the optimal amount at date 1. For "small" values of Δ, cost-based transfer pricing then still performs well in the following sense:

Proposition 5 *Suppose only the buying division invests and (A4) holds. For values of Δ sufficiently close to zero, cost-based transfer pricing dominates negotiated transfer pricing for any $\gamma \in (0, 1)$.*

The proof of Proposition 5 is omitted because the arguments involved are straightforward. For any $\gamma \in (0, 1)$ the performance of negotiated transfer pricing is bounded away from first-best profits due to the hold-up problem. On the other hand, cost-based transfer pricing does approach first-best profits as Δ goes to zero.

In light of Proposition 2, we note that the performance comparison of the two regimes remains indeterminate for intermediate values of Δ, when only the buying division invests. It would be desirable to examine in future research how quickly the relative performance of cost-based transfer pricing degrades as the measurement error, Δ, increases.

4. Extensions

4.1. Two-Part Transfer Pricing

In order to avoid the problem of mark-ups and the resulting trade inefficiencies, managerial accounting textbooks often propose a two-part transfer pricing scheme, where the buying division pays a periodic lump-sum fee, T, in addition to a variable (unit) price, v. Suppose the selling division can set the fixed fee T in addition to the unit variable cost v. If the buying division decides to purchase q units of the intermediate good, the transfer payment would be $t = v \cdot q + T$.

The supplying division now has even more bargaining power. Its only constraint is that the buyer may refuse trade altogether, resulting in a zero transfer payment. With constant marginal cost, the selling division will set $v = c(\theta, I_1)$ and $T = M(\theta, I)$ to extract the entire surplus. As a consequence, this scheme yields ex-post efficient trade, shifts the entire contribution margin to the seller and corresponds to negotiations with $\gamma = 1$. In the case of one-sided seller investments we thus conclude that two-part cost-based transfer pricing yields optimal performance. In contrast, when the buying division undertakes investments, a two-part system provides no investment incentives, and therefore performs worse than negotiated transfer pricing. With bilateral investments the resulting tradeoff depends on the functional forms of $w_i(I_i)$: if $w_i'(\cdot)$ is small relative to $w_2'(\cdot)$ for a wide range of values, then seller investments are more productive and the firm would prefer a two-part cost-based scheme.

Comparing two-part with linear cost-based transfer pricing, the former clearly dominates if only the selling division invests. If only the buyer invests, then a tradeoff arises, since the two-part scheme entails no investment incentives but does result in ex-post efficient trade. Similarly, the comparison will be ambiguous with bilateral investments.

Some textbooks recommend to let divisions negotiate the lump-sum payment under a two-part transfer pricing scheme rather than basing it on the seller's cost report alone; see, for example, Hansen and Mowen (1994). As long as the divisions have symmetric information, the lump-sum payment has only distributional consequences. Two alternative sequences of events are conceivable. First, the lump-sum is negotiated *after* the seller has quoted his variable standard cost and the buyer has ordered the amount that maximizes his contribution margin. This scenario exactly replicates negotiated transfer pricing since the divisions will maximize total contribution margin and hence agree on $q^*(\cdot)$.

Second, if the lump-sum is negotiated *before* the seller has quoted his unit cost, then there will be trade distortions as well as hold-up problems since the seller will again engage in monopolistic price setting. As a consequence, this hybrid form is dominated by "pure" negotiated transfer pricing.

4.2. Multiple Internal Buyers

In many multidivisional firms the intermediate good produced by one division serves as an input to several downstream divisions. We first consider a scenario where the supplying division can undertake cost reducing specific investments. Under cost-based transfer pricing, the seller charges a unit price that is a weighted average of the individual monopoly prices. If all marginal revenue functions as well as production costs are linear, then Proposition 1 continues to hold, since the total quantity sold at the weighted monopoly price coincides with the sum of the individual monopoly quantities and hence equals half the efficient total quantity (Tirole, 1988, 139). As a consequence, the seller has the same investment incentives under cost-based transfer pricing as under negotiated transfer pricing where the parties have equal bargaining power. Thus, negotiated transfer pricing continues to dominate, although this reasoning does not account for the costs associated with multilateral bargaining

The relative performance of cost-based transfer pricing may improve if one of the buying divisions undertakes specific investments. Suppose, for instance, that there are two buying divisions and one of them can invest. The investment incentives will then be driven by the relative slopes of the internal demand curves. If the investing division has an "inelastic" marginal revenue function, i.e., if $\partial q/\partial v$ is small (in absolute value) relative to the other buying division, then the hold-up effect described in Section 2 will be mitigated. If the seller tried to appropriate the investment returns through a higher monopoly price, it would forgo significant sales to the other division.

5. Conclusion

This paper has compared the performance of negotiated and standard cost-based transfer pricing. A cost-based scheme may mitigate hold-up problems in connection with divisional investments. In many situations of interest, however, the attendant monopoly inefficiencies outweigh the benefits of mitigated hold-up problems resulting in higher expected firm profits under negotiated transfer pricing. Standard-cost transfer pricing becomes the superior alternative when buyer investments are important for the firm and the selling division does not have much leeway with its standard-cost report.

The relative strength of negotiated transfer pricing in our analysis must be qualified in at least two ways. First, it is commonly accepted that firms view the need for "haggling" to be a major cost and drawback of negotiated transfer pricing. That could be particularly significant with repeated transactions and more than just two divisions. Secondly, our scenario of symmetric information across divisions at the transaction stage is particularly beneficial for a negotiation regime. When divisions have incomplete information about the other's valuation, then the parties will generally not be able to realize the entire gains from trade. As shown in Baldenius (1999), other transfer pricing schemes may then have an advantage in asymmetric information settings.

The present paper can be viewed as a step towards a taxonomy of alternative transfer pricing mechanisms. There are several other pricing schemes used in practice which could be compared with the two mechanisms considered in our model. For instance, in situations where the intermediate good can be sold externally, the firm could also consider market-based prices. When the external market is imperfectly competitive, the market-based transfer price will generally be too high, again leading to trading distortions. At the same time, the presence of an external market will affect the performance of negotiated transfer pricing since the selling division gains an outside option. The model considered in this paper may prove useful in assessing the relative performance of alternative transfer pricing mechanisms used in practice.

Appendix

Proof of Lemma 1: Suppose that $I_1^s \leq I_1^n$, yet $\Pi^s \geq \Pi^n$. The expected firm profit under cost-based transfer pricing is

$$\begin{aligned}\Pi^s &= E_\theta[R(q^s(\theta, I_1^s), \theta) - C(q^s(\theta, I_1^s), \theta, I_1^s)] - w_1(I_1^s)\\ &< E_\theta[R(q^*(\theta, I_1^s), \theta) - C(q^*(\theta, I_1^s), \theta, I_1^s)] - w_1(I_1^s)\\ &\leq E_\theta[R(q^*(\theta, I_1^n), \theta) - C(q^*(\theta, I_1^n), \theta, I_1^n)] - w_1(I_1^n)\\ &= \Pi^n,\end{aligned}$$

a contradiction. The first inequality follows by definition of $q^*(\cdot)$, which by assumption is unique and interior. The second inequality follows from the fact that, according to (A2), $\Pi^*(I_1)$ is monotone increasing on $[0, I_1^*]$ and that $I_1^s \leq I_1^n$. Overinvestment under either transfer pricing scheme can be ruled out by the arguments provided in the proof of Lemma 3, below. (A similar argument can be employed to show that $\Pi^s < \Pi^n$ if only the buying division invests, (A4) holds, and $I_2^s \leq I_2^n$.) ■

Proof of Lemma 2: We prove that $q^*(\theta, I_1) \geq 2 \cdot q^s(\theta, I_1)$ if and only if $r'(q, \theta)$ is convex in q. By revealed preference, we know that $q^*(\theta, I)$ maximizes $r(q, \theta) - C(q, \theta, I_1)$ and hence

$$r'(q^*(\theta, I_1), \theta) - c(\theta, I_1) = 0. \tag{14}$$

At the same time, $q^s(\theta, I)$ maximizes $r'(q,\theta) \cdot q - C(q, \theta, I_1)$, since the buyer's marginal revenue curve represents his demand function for the input, which yields

$$r''(q^s(\theta, I_1), \theta) \cdot q^s(\theta, I_1) + r'(q^s(\theta, I_1), \theta) - c(\theta, I_1) = 0. \tag{15}$$

Subtracting and rearranging the first-order conditions (14) and (15), we have

$$r'(q^*(\theta, I_1), \theta) - r'(q^s(\theta, I_1), \theta) = r''(q^s(\theta, I_1), \theta) \cdot q^s(\theta, I),$$

or, equivalently,

$$\int_{q^s(\theta,I_1)}^{q^*(\theta,I_1)} r''(u,\theta)du = r''(q^s(\theta, I_1), \theta) \cdot q^s(\theta, I_1). \tag{16}$$

Convexity of $r'(q,\theta)$ means that $r''(q,\theta)$ is increasing in q and hence provides a lower bound on the left-hand side of the equality:

$$\begin{aligned}\int_{q^s(\theta,I_1)}^{q^*(\theta,I_1)} r''(u,\theta)du &> \int_{q^s(\theta,I_1)}^{q^*(\theta,I_1)} r''(q^s(\theta, I_1), \theta)\, du \\ &= r''(q^s(\theta, I_1) \cdot [q^*(\theta, I_1) - q^s(\theta, I_1)].\end{aligned}$$

Substituting this last expression into (16), and dividing by $r''(q^s(\theta, I_1) < 0$, we get

$$q^*(\theta, I_1) - q^s(\theta, I_1) > q^s(\theta, I_1),$$

completing the proof. ■

Proof of Lemma 3: The proof is by contradiction. For $\gamma = \frac{1}{2}$, let

$$M_1^n(I_1) = \gamma E_\theta[M(\theta, I_1)] = \frac{1}{2} E_\theta[M(\theta, I_1)]$$

denote the expected contribution margin accruing to Division 1 under negotiated transfer pricing, given it has invested an amount I_1. Similarly, under cost-based transfer pricing:

$$M_1^s(I_1) = E_\theta[v^s(\theta, I_1) \cdot q(v^s(\theta, I_1), \theta) - c(\theta, I_1) \cdot q(v^s(\theta, I_1), \theta)].$$

Using the Envelope Theorem, the respective marginal investment returns are

$$M_1^{n'}(I_1) = \gamma E_\theta[q^*(\theta, I_1)] \quad \text{and} \quad M_1^{s'}(I_1) = E_\theta[q^s(\theta, I_1)].$$

If $r'(q,\theta)$ is convex in q, then, according to Lemma 2, we have

$$M_1^{n'}(I_1) \geq M_1^{s'}(I_1), \tag{17}$$

for all I_1. Now suppose that, contrary to our claim, $I_1^n < I_1^s$ holds. By revealed preference, $I_1^n \in \arg\max_{I_1}\{M_1^n(I_1) - w_1(I_1)\}$ and $I_1^s \in \arg\max_{I_1}\{M_1^s(I_1) - w_1(I_1)\}$. Therefore:

$$\begin{aligned}M_1^n(I_1^n) - w_1(I_1^n) &\geq M_1^n(I_1^s) - w_1(I_1^s), \\ M_1^s(I_1^s) - w_1(I_1^s) &\geq M_1^s(I_1^n) - w_1(I_1^n).\end{aligned}$$

Adding and rearranging yields

$$\int_{I_1^s}^{I_1^n} M_1^{n'}(I_1)dI_1 \geq \int_{I_1^s}^{I_1^n} M_1^{s'}(I_1)dI_1.$$

If now $I_1^n < I_1^s$ then there must exist some value I_1 such that $M_1^{s'}(I_1) > M_1^{n'}(I_1)$, which contradicts (17). Thus, we conclude that $I_1^n \geq I_1^s$. ■

Proof of Proposition 2: First note that Lemma 1 readily extends to the case of buyer investments, provided (A4) holds. As a consequence, we only have to show that $I_2^n \geq I_2^s$. A sufficient condition for this to hold is that the buyer's marginal investment returns are uniformly greater under negotiation.

Under negotiated transfer pricing, investment satisfies:

$$M_2^{n'}(I_2) = (1-\gamma)E_\theta[q^*(\theta, I_2)],$$

while, as argued in (9), under cost-based transfer pricing, we have

$$M_2^{s'}(I_2) = E_\theta\left[\left(1 - \frac{\partial v^s(\theta, I_2)}{\partial I_2}\right) \cdot q^s(\theta, I_2)\right].$$

In order to evaluate the additional hold-up term $\partial v^s(\theta, I_2)/\partial I_2$, we invoke a result from Baldenius and Reichelstein (1997). There it is shown that $\partial v^s(\cdot)/\partial I_2 \geq \frac{1}{2}$, if $r'(q,\theta)$ is concave in q. Furthermore, given $\bar{I}_2 \leq c(\theta)$ for all θ, a sufficient condition for the monopoly price to be increasing in buyer investments, i.e., $\partial v^s(\cdot)/\partial I_2 \geq 0$, is that $r'(q,\theta)$ be log-concave in q.

Condition (i). If $r'(q,\theta)$ is concave in q, then $\partial v^s(\cdot)/\partial I_2 \geq \frac{1}{2}$, for all θ. Since, at the same time, $q^s(\cdot) \leq q^*(\cdot)$, we find that $M_2^{s'}(I_2) \leq \frac{1}{2}E_\theta[q^*(\theta, I_2)] \leq M_2^{n'}(I_2)$. Thus $I_2^n \geq I_2^s$.

Condition (ii). If $r'(q,\theta)$ is log-concave in q, then $\partial v^s(\cdot)/\partial I_2 \geq 0$. Convexity of $r'(q,\theta)$ in q implies $q^s(\cdot) \leq \frac{1}{2}q^*(\cdot)$, as shown in Lemma 2. Again, we find $M_2^{s'}(I_2) \leq \frac{1}{2}E_\theta[q^*(\theta, I_2)]$, showing that $I_2^n \geq I_2^s$. ■

Proof of Lemma 4: We shall prove a slightly more general claim. It will be convenient to define the auxiliary function

$$\pi_i^*(I_1, I_2, \eta_i) \equiv \eta_i \cdot E_\theta[M(\theta, I)] - w_i(I_i), \tag{18}$$

as Division i's payoff function for given investments (I_1, I_2), followed by ex-post efficient quantities. The parameter $\eta_i \geq 0$ denotes the fraction of the ex-post achievable contribution margin that accrues to Division i. Notice that, in the special case of negotiated transfer pricing, we find that $\eta_1^n = \gamma$ and $\eta_2^n = 1-\gamma$, while the first-best investments I^* would result if $\eta_1 = \eta_2 = 1$, i.e., each division fully internalizes the firm's objective function. The lemma follows from the following two claims:

Claim 1 *Given (A5)–(A7) and any $\eta \equiv (\eta_1, \eta_2) \leq (1, 1)$, there does not exist a Nash equilibrium such that $I_i(\eta) \geq I_i^*$, for some $i \in \{1, 2\}$.*

Claim 2 *Given (A5)–(A7), for any* η*, with* $\eta_1 + \eta_2 \leq 1$*, there exists a unique Nash equilibrium* $I(\eta)$ *such that* $I_i(\eta) < I_i^*$ *for all* $i \in \{1, 2\}$*.*

Proof of Claim 1: The proof employs supermodularity techniques developed by Topkis (1978) and Milgrom and Roberts (1990, henceforth MR). It is immediate to verify that the payoff functions π_i^* as in (18) satisfy the supermodularity conditions (A1′)–(A5′) stated in MR, pp. 1264–7: the strategy spaces $[0, \bar{I}_i]$ are closed intervals on the real line, π_i^* is twice continuously differentiable on $[0, \bar{I}_i]$, and π_i^* shows increasing differences in both investments I_1 and I_2, as well as in investments and the parameters $\eta_k : \partial^2\pi_i^*/\partial I_1 \partial I_2 \geq 0$, and $\partial^2\pi_i^*/\partial I_i \partial \eta_k \geq 0$, for all $i, k \in \{1, 2\}$.

A Corollary to Theorem 6 proven in MR, p. 1267, states that the lowest and highest Nash equilibria are nondecreasing in the parameters η_1 and η_2. Since (I_1^*, I_2^*) by assumption is the unique first-best equilibrium, it is trivially also the highest one. Applying MR's Corollary with respect to both η_1 and η_2, we find that the highest equilibrium for each $(\eta_1, \eta_2) \leq (1, 1)$ must be weakly less than first-best in both components, completing the proof of Claim 1. Finally, since at least one η_i is less than one, (A6) ensures strict inequalities, that is $I_i(\eta) < I_i^*$ for $i \in \{1, 2\}$; see Edlin and Shannon (1998). ■

Proof of Claim 2: By Claim 1 we can confine our search for Nash equilibria to the interval $[0, I_1^*] \times [0, I_2^*]$. A corollary to Theorem 5 on page 1266 in MR ensures that there exists at least one pure strategy Nash equilibrium. By (A6), the profit function $\Pi^*(I_1, I_2)$ is concave in each argument on this interval.

If $\eta_1 + \eta_2 \leq 1$, a Nash equilibrium $I(\eta)$ satisfied the first-order conditions associated with $\pi_i(\cdot)$ as given in (18):

$$\frac{\partial \pi_1^*}{\partial I_1} = \eta_1 E_\theta[q^*(\theta, I_1(I_2, \eta_1), I_2)] - w_1'(I_1(\cdot)) = 0, \tag{19}$$

$$\frac{\partial \pi_2^*}{\partial I_2} = \eta_2 E_\theta[q^*(\theta, I_1, I_2(I_1, \eta_2))] - w_2'(I_2(\cdot)) = 0. \tag{20}$$

Differentiating these conditions, we have

$$\frac{\partial I_1(I_2, \eta_1)}{\partial I_2} = \frac{\eta_1 E_\theta\left[\frac{1}{-r''(q^*(\cdot),\theta)}\right]}{w_1''(I_1) - \eta_1 E_\theta\left[\frac{1}{-r''(q^*(\cdot),\theta)}\right]} = \left[\frac{w_1''(I_1)}{\eta_1 E_\theta\left[\frac{1}{-r''(q^*(\cdot),\theta)}\right]} - 1\right]^{-1},$$

$$\frac{\partial I_2(I_1, \eta_2)}{\partial I_1} = \left[\frac{w_2''(I_2)}{\eta_2 E_\theta\left[\frac{1}{-r''(q^*(\cdot),\theta)}\right]} - 1\right]^{-1}.$$

Defining $\phi(I_1, \eta_1) \equiv I_1^{-1}(I_1, \eta_1)$ as the inverse of the seller's reaction function, a sufficient condition for there to be a unique Nash equilibrium is that

$$\frac{\partial\phi(I_1,\eta_1)}{\partial I_1} > \frac{\partial I_2(I_1,\eta_2)}{\partial I_1},$$

for all I_1, η_1, η_2.

Suppose that this is not the case. Then,

$$\frac{\partial\phi(I_1,\eta_1)}{\partial I_1} \leq \frac{\partial I_2(I_1,\eta_2)}{\partial I_1}, \text{ or equivalently, } \prod_{i=1}^{2}\left[\frac{w_i''(I_i)}{\eta_i E_\theta\left[\frac{1}{-r''(q^*(\cdot),\theta)}\right]} - 1\right] \leq 1.$$

The preceding inequality is equivalent to

$$w_1''(\cdot)\cdot w_2''(\cdot) \leq (\eta_1 w_2''(\cdot) + \eta_2 w_1''(\cdot))\cdot E_\theta\left[\frac{1}{-r''(q^*(\cdot),\theta)}\right].$$

But since $\eta_i \leq 1$ and $\eta_1 + \eta_2 \leq 1$, by assumption, we find that the right-hand side of this inequality is less than or equal to

$$\max\{w_1''(\cdot), w_2''(\cdot)\}\cdot E_\theta\left[\frac{1}{-r''(q^*(\cdot),\theta)}\right]$$
$$< \max\{w_1''(\cdot), w_2''(\cdot)\}\cdot\min\{w_1''(\cdot), w_2''(\cdot\} = w_1''(\cdot)\cdot w_2''(\cdot),$$

where the inequality follows from the concavity assumption in (A6). Thus, we obtain a contradiction, and since $\partial\phi(I_1,\eta_1)/\partial I_1 > \partial I_2(I_1,\eta_2)/\partial I_1$, there exists a unique equilibrium. Claim 1 together with (A7) show that this equilibrium is in the interior of $[0, I_1^*] \times [0, I_2^*]$. That completes the proof of Lemma 4. ■

Proof of Proposition 3: Under the conditions stated in Proposition 3, the revealed preference arguments employed in the proofs of Lemma 3 and Proposition 2 apply again to show that, for given investment I_j, Division i invests weakly more under negotiation than under cost-based transfer pricing.

As indicated in the main text, we consider finite strategy sets $\mathbf{I_1}$ and $\mathbf{I_2}$ such that the unique pure strategy equilibrium under negotiated transfer pricing obtained in Lemma 4 is an element of $\mathbf{I_1}\times\mathbf{I_2}$, i.e., $I_1^n = I_1^k$ and $I_2^n = I_2^l$. That is, I_1^n is the $(k+1)$-th element of $\mathbf{I_1}$, and I_2^n is the $(l+1)$-th element of $\mathbf{I_2}$. As a final piece of notation, let p_1^{si} denote the probability that Division 1 puts on investment I_1^i under cost-based transfer pricing, so that $p_1^s \equiv (p_1^{s0}, p_1^{s1}, \ldots, p_1^{sm})$ is the seller's mixed strategy under this scheme, with $\sum_{i=0}^m p_1^{si} = 1$. Similar notation holds for Division 2, where $p_2^s \equiv (p_2^{s0}, p_2^{s1}, \ldots, s_2^{s\tilde{m}})$ characterizes the buyer's mixed strategy under this scheme.

Under negotiated transfer pricing the unique pure strategy equilibrium is denoted by $p_1^n \equiv (0,\ldots,p_1^{nk}=1,\ldots,0)$ and $p_2^n \equiv (0,\ldots,p_2^{nl}=1,\ldots,0)$. Let $\hat{I}_1^s \equiv \max\{I_1^i \mid p_1^{si} > 0\}$ and $\hat{I}_2^s \equiv \max\{I_2^i \mid p_2^{si} > 0\}$. A sufficient condition now for Proposition 3 to hold is that $\hat{I}_1^s \leq I_1^n$ and $\hat{I}_2^s \leq I_2^n$, or, equivalently: $p_1^{si} = p_2^{sj} = 0$, for all $i > k$, $j > l$.

Suppose that this is not the case, and $\hat{I}_1^s > I_1^n$ would hold. Then, we know that (i) $(I_1^n)^{-1}(\hat{I}_1^s) \equiv \phi(\hat{I}_1^s) > I_2^n(\hat{I}_1^s)$, by Lemma 4, and (ii) $I_1^n(\hat{I}_2^s) \geq \hat{I}_1^s$ and $I_2^n(\hat{I}_1^s) \geq \hat{I}_2^s$, by revealed preference. Using (i) and (ii), we obtain a contradiction:

$$\hat{I}_1^s \equiv I_1^n(\phi(\hat{I}_1^s)) > I_1^n(I_2^n(\hat{I}_1^s)) \geq I_1^n(\hat{I}_2^s) \geq \hat{I}_1^s.$$

A similar chain of inequalities shows that $\hat{I}_2^s \leq I_2^n$.

Finally, let $\Pi^s(p_1^s, p_2^s)$ denote the expected firm profit under cost-based transfer pricing and $\Pi^n(I_1^n, I_2^n)$ denote that under negotiated transfer pricing. Note that $\Pi^s(\cdot)$ is a convex combination of the expected profits associated with the strategies in the support of the mixed strategy profile (p_1^s, p_2^s). Hence:

$$\begin{aligned}
\Pi^s(p_1^s, p_2^s) &= \sum_{i=0}^{m}\sum_{j=0}^{\tilde{m}} p_1^{si} p_2^{sj}[E_\theta[R(q^s(\theta, I_1^i, I_2^j), I_2^j) - C(q^s(\theta, I_1^i, I_2^j), I_1^i)] \\
&\qquad - w_1(I_1^i) - w_2(I_2^j)] \\
&< \sum_{i=0}^{m}\sum_{j=0}^{\tilde{m}} p_1^{si} p_2^{sj}[E_\theta[R(q^*(\theta, I_1^i, I_2^j), I_2^j) - C(q^*(\theta, I_1^i, I_2^j), I_1^i)] \\
&\qquad - w_1(I_1^i) - w_2(I_2^j)] \\
&\leq E_\theta[R(q^*(\theta, I_1^n, I_2^n), I_2^n) - C(q^*(\theta, I_1^n, I_2^n), I_2^n)] - w_1(I_1^n) - w_2(I_2^n) \\
&= \Pi^n(I_1^n, I_2^n).
\end{aligned}$$

The first inequality reflects the ex-post inefficiencies in trade under cost-based transfer pricing, and the second inequality holds due to (A6), together with the fact that $(I_1^n, I_2^n) \geq (\hat{I}_1^s, \hat{I}_2^s)$. ■

Proof of Proposition 4: It suffices to show that for any Δ, the resulting investment under cost-based transfer pricing is less than under negotiated transfer pricing. We recall from equation (5) in Section 2 that the seller's investment, I_1^n, under negotiated transfer pricing satisfies the equation:

$$w_1'(I_1^n) = \gamma \cdot E_\theta[q^*(\theta, I_1^n)],$$

if $c(\theta, I_1) = c(\theta) - I_1$. Under cost-based transfer pricing, the selling division chooses I_1^s such that

$$I_1^s \in \arg\max_{I_1}\{E_\theta[M_1^s(\theta, I_1, \Delta)] - w_1(I_1)\},$$

where

$$M_1^s(\theta, I_1, \Delta) \equiv [v^s(\theta, I_1, \Delta) - (c(\theta) - I_1)] \cdot q(v^s(\theta, I_1, \Delta), \theta).$$

Since $\gamma \geq \frac{1}{2}$, Lemma 3 shows that $I_1^n \geq I_1^s$ if for all θ:

$$\frac{\partial}{\partial I_1} M_1^s(\theta, I_1, \Delta) \leq \frac{1}{2} \cdot q^*(\theta, I_1),$$

i.e., the marginal return of investment under cost-based transfer pricing is uniformly lower than the marginal return under negotiated transfer pricing.

Given the constraints on the seller's standard cost, the transfer price $v^s(\theta, I_1, \Delta)$ satisfies:

$$v^s(\theta, I_1, \Delta) = \min\left\{\frac{1}{2} \cdot [a(\theta) + c(\theta) - I_1], c(\theta) - I_1 + \Delta\right\},$$

since $\frac{1}{2}[a(\theta) + c(\theta) - I_1]$ is just the unconstrained monopoly price when the marginal revenue curve is linear. Let $I_1^0(\theta)$ be such that

$$\frac{1}{2} \cdot [a(\theta) + c(\theta) - I_1^0(\theta)] = c(\theta) - I_1^0(\theta) + \Delta.$$

First, consider any $I_1 \in [0, \bar{I}_1]$ such that $I_1 < I_1^0(\theta)$ (this set may be empty). Then $v^s(\theta, I_1, \Delta) = \frac{1}{2} \cdot [a(\theta) + c(\theta) - I_1]$, and

$$q(v^s(\theta, I_1, \Delta), \theta) = \frac{a(\theta) - c(\theta) + I_1}{4 \cdot b(\theta)} = \frac{1}{2} \cdot q^*(\theta, I_1).$$

By the Envelope Theorem, we have:

$$\frac{\partial}{\partial I_1} M_1^s(\theta, I_1, \Delta) = q(v^s(\theta, I_1, \Delta), \theta) = \frac{1}{2} \cdot q^*(\theta, I_1).$$

Secondly, consider any $I_1 \in [0, \bar{I}_1]$ such that $I_1 > I_1^0(\theta)$ (again, this set may be empty). Then $v^s(\theta, I_1, \Delta) = c(\theta) - I_1 + \Delta$, and

$$q(v^s(\theta, I_1, \Delta), \theta) = q^*(\theta, I_1) - \frac{\Delta}{2b(\theta)}.$$

In this case, we obtain:

$$\frac{\partial}{\partial I_1} M_1^s(\theta, I_1, \Delta) = \Delta \cdot \frac{\partial}{\partial I_1} q^*(\theta, I_1) = \frac{\Delta}{2 \cdot b(\theta)}.$$

Because $\Delta \leq \frac{1}{2} \cdot [a(\theta) - c(\theta) + I_1]$ whenever $I_1 > I_1^0(\theta)$, it follows that

$$\frac{\Delta}{2 \cdot b(\theta)} \leq \frac{1}{2} \cdot q^*(\theta, I_1).$$

In particular, we notice that $M_1^s(\theta, I_1, \Delta)$ is differentiable in I_1 for all θ. Furthermore,

$$\frac{\partial}{\partial I_1} M_1^s(\theta, I_1, \Delta) \leq \frac{1}{2} \cdot q^*(\theta, I_1),$$

for all θ. ■

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Notes

1. See Price Waterhouse (1984), Eccles (1985), Shelanski (1993) and Tang (1993). Among cost-based transfer pricing schemes, most textbooks recommend standard over actual cost, since the supplying division has an incentive to keep actual cost low, and both divisions know at the outset what the transfer price will be under standard cost-based transfer pricing: see Horngren, Foster and Datar (1994, p. 910).
2. See, for example, Williamson (1985), Grossman and Hart (1986) and Holmström and Tirole (1991).
3. See, for instance, Chung (1991) and Edlin and Reichelstein (1995).
4. The Price Waterhouse (1984) survey indicates that for the overwhelming majority of intrafirm transactions, divisions do not employ "formal contracts." Recent research which takes the perspective that the good in question cannot be specified contractually at the outset includes Grossman and Hart (1986) and Holström and Tirole (1991). Che and Hausch (1997) show that with so-called cooperative investments, upfront contracts will frequently be of no use.
5. Eccles and White (1988, p. 27), note that: "An especially common complaint by the buying profit center is that standard costs include provisions for slack and are set at a conservative level." See also Horngren, Foster and Datar (1997, p. 909, "Points to Stress").
6. See Harris, Kriebel and Raviv (1982), Amershi and Cheng (1990), Mookherjee and Reichelstein (1992), Wagenhofer (1994), Vaysman (1996, 1998), Christensen and Demski (1998) and Schiller (1997).
7. Aside from considering general revenue curves for the buying division, the present paper extends the analysis in Baldenius and Reichelstein (1998) by recognizing potential constraints on the seller's cost report (Section 3).
8. Eccles (1985) and Merchant (1989) provide evidence for the hypothesis that divisional managers are primarily focussed on the income of their own divisions.
9. One possible interpretation is that both division managers observe θ and (I_1, I_2). Alternatively, a manager may simply observe the valuation of the other division without being able to disentangle the effects of θ and I.
10. Anctil and Dutta (1999) analyze the tradeoff between divisional and firm-wide performance evaluation in a model where risk-averse agents make effort and investment decisions.
11. Although the Nash solution has a natural appeal and can be obtained as the outcome of certain non-cooperative bargaining games, we allow for more general values of γ to check for the robustness of our results.
12. All proofs are provided in the Appendix.
13. For general demand functions, we find that $r'(q, \theta)$ is concave in q if and only if $3 \cdot P''(q, \theta) + P'''(q, \theta) \cdot q \leq 0$.
14. A differentiable function $f(x)$ is log-concave if the ratio $(f'(x)/f(x))$ is decreasing in x.
15. Divisional investments in this case are strategic complements and we can employ techniques introduced by Topkis (1978), and further developed by Milgrom and Roberts (1990), for the analysis of supermodular games. Supermodular games are characterized by increasing differences, i.e., the marginal utility of increasing Division i's strategy is increasing in Division j's strategy.

16. In particular, we assume that the range of admissible cost reports, i.e., those for which the controller cannot dispute the seller's ex-ante cost calculation, moves directly with the underlying true cost. A more general model would allow for detection probabilities which depend on both the seller's report and the true cost.
17. Sahay (1997) examines optimal mark-ups in a setting where actual cost is verifiable.

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