Intrafirm Trade, Bargaining Power, and Specific Investments

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Abstract. This paper compares the performance of standard-cost with negotiated transfer pricing under asymmetric information. Negotiated transfer pricing generally achieves higher expected contribution margins, as this method tends to be more efficient in aggregating private information into a single transfer price. Standard-cost transfer pricing confers more bargaining power to the supplier and therefore generates better incentives for this division to undertake specific investments. The opposite holds for buyer investments. If a corporate controller has disaggregated information about divisional costs and revenues, then the firm can improve upon the performance of standard-cost transfer pricing by setting a centralized transfer price equal to expected cost plus a suitably chosen mark-up.

Keywords: Transfer pricing, asymmetric information, specific investments, hold-up problem

Intracompany transfers of intermediate products are often conducted under conditions of asymmetric information. The manager of the supplying division frequently has private information about the cost of producing the intermediate good, whereas the manager of the buying division has better knowledge regarding the net revenues from selling the final product. Accounting textbooks tend to advocate negotiated transfer pricing as a mechanism that permits divisional managers to incorporate their local information into transfer pricing and quantity decisions (Kaplan and Atkinson (1998, 461)). At the same time, the economics literature has established that negotiations under asymmetric information entail inefficiencies: profitable transactions are forgone as the parties strive for more favorable prices by overstating cost and understating revenues (Myerson and Satterthwaite (1983)). For the theory of transfer pricing, it does not seem to be well-understood how any inefficiencies under negotiated transfer pricing compare with those under commonly-used alternative mechanisms.

This paper conducts a performance comparison of negotiated and standard-cost transfer pricing in a setting of asymmetric information and incomplete contracting. In our binary quantity model, the transfer pricing scheme serves two incentive purposes. First, divisional managers should transfer the intermediate good whenever this is profitable from a firm-wide perspective. The second purpose is to provide incentives for the divisions to undertake relationship-specific investments. For instance, the selling division may acquire equipment up-front in order to reduce its variable production cost or the buying division may invest in marketing activities. If a division is engaged in many different transactions, then investments can generally not be linked to certain products and hence are not contractible. In such a setting, negotiations have been shown to suffer from underinvestment—or “hold-up”—
problems: the investing division bears the entire investment costs while the other division receives a share of the returns.  

In a recent study, Baldenius, Reichelstein, and Sahay (1999) develop a symmetric information model with continuous quantities to compare the performance of standard-cost and negotiated transfer pricing. In their setting, negotiated transfer pricing is in many cases the dominant mechanism, primarily because it always yields efficient trade. The present paper reexamines this performance comparison under the assumption that divisional managers have private information. We show that trade distortions arising from bargaining under asymmetric information tend to “compound” the underinvestment problem. The reason is that investment returns are determined by the probability that trade occurs. Negotiated transfer pricing therefore biases the divisional investments for two reasons: the total returns from investing are suboptimal, and the investing party anticipates that it will have to share these returns in the negotiation process.

Under standard-cost transfer pricing, if the supplying division has discretion in reporting costs, then this division essentially gains monopoly power and tends to report a transfer price well above its cost. This monopolistic behavior induces trade distortions, which, in turn, lower investment incentives along the lines described in Baldenius, Reichelstein, and Sahay (1999). While, in practice in the present paper, the selling division may be constrained in its ability to exaggerate cost, the model setup captures the essential notion that a standard-cost mechanism grants the seller a first-mover advantage and thereby confers more bargaining power to this division, as compared with negotiations. As in the symmetric information model referred to above, we find that a system of standard-cost transfer pricing avoids hold-up problems for the supplier. At the same time, buyer investments suffer from severe hold-up problems since the transfer price set by the supplier will reflect any investment undertaken by the buyer.

A central new insight provided by this paper is that trade is in many cases less efficient under standard-cost transfer pricing than under negotiations. Standard-cost transfer pricing suffers from the principal disadvantage that the price reflects only the seller’s information. Under negotiations, in contrast, the payment is responsive to both divisions’ information. One scenario where standard-cost transfer pricing entails fewer distortions than negotiations occurs when the supplier is “fairly knowledgeable” about the buyer’s revenues. Then the quantity traded under standard-cost transfer pricing approaches first-best, while negotiations still suffer from inefficiencies.

If only the seller invests, then the standard-cost mechanism approaches optimal performance in case of a fairly knowledgeable seller. However, if the buyer’s revenues are highly uncertain to the seller, then the firm faces a tradeoff between higher seller investments under standard-cost transfer pricing versus more efficient trade under negotiations. In settings where only the buying division invests, the relative performance of standard-cost transfer pricing degrades as the negotiation mechanism generally tends to dominate along both dimensions—trade efficiency and investment incentives.

The analysis departs in several respects from existing literature. Most of the recent work on transfer pricing has adopted a mechanism design approach: a central office designs optimal rules for allocating resources and compensating divisions based on their messages. The present paper takes a more applied—and decentralized—view of intrafirm trade: the center
is confined to choosing generic transfer pricing rules that are essentially interpreted as means to allocate bargaining power among the divisions. The two candidate mechanisms are modeled as special cases of a general bargaining procedure with the only difference being that standard-cost transfer pricing confers more bargaining power to the supplier. Our analysis abstracts entirely from compensation issues. We assume throughout that division managers seek to maximize their expected divisional income without modeling any underlying moral hazard problems.

Our results suggest the following pattern of how the firm should optimally allocate bargaining power among the divisions. To minimize hold-up problems, bargaining power should reside with the investing division: if the supplier invests, then in some cases standard-cost transfer pricing achieves higher expected firm profit; however, negotiated transfer pricing tends to dominate if the buyer invests. On the other hand, to minimize trade distortions, bargaining power should be given to the division that has “more private information.” To verify this intuition, we investigate limit scenarios where only one division has private information. We also show that private information partly shields a division’s investment from hold-up problems: the other division has to bargain more cautiously, not knowing the investing party’s reservation price.

In the main part of the analysis, the central office does not have access to information necessary for playing an active role in setting the transfer price; instead it only assigns the divisions certain rights and obligations. We also consider a model extension where the corporate controller receives noisy signals about the division’s environments, which allows it to compute a centralized transfer price. It then turns out that the firm can improve upon the performance of standard-cost transfer pricing by centrally setting the transfer price equal to expected cost plus a suitably chosen mark-up. However, if both divisions have private information, the firm faces a tradeoff between negotiated and centralized transfer pricing: negotiations yield more efficient trade while the centralized mechanism avoids hold-up problems and hence generates better investment incentives.

Section 1 of this paper describes the basic model. In Section 2, the transfer pricing schemes are introduced. Sections 3 and 4 contain the performance comparison for settings where either the supplying or the buying division invests, respectively. In Section 5, we ask whether the central office should actively engage in setting the standard-cost transfer price, if it has some prior cost estimate. Section 6 concludes the paper.

1. The Model

We analyze a firm consisting of two profit centers. The supplying division (Division 1) manufactures an intermediate good and ships it to the buying division (Division 2), which uses it as an input in its production process and ultimately sells a final product externally. The model involves four dates. At date 0, the firm commits to a transfer pricing scheme. At date 1, the managers decide upon their respective investment levels: the supplying division chooses \( I_1 \) from the interval \([0, T_1]\), and the buying division chooses \( I_2 \in [0, T_2] \). These investments result in divisional fixed costs, denoted by \( w_i(I_i), i = 1, 2 \). Investments are assumed observable to both divisional managers. At date 2, the managers privately learn
their respective valuations (types): Manager 1 observes his production cost type \( \theta_1 \), and Manager 2 observes his net revenue type \( \theta_2 \). At date 3, the divisional managers agree on whether to trade the intermediate good, \( q \in [0, 1] \), and on the corresponding transfer payment, \( t \in \mathbb{R}_+ \).

The supplier’s costs of manufacturing the good are \( C(\theta_1, I_1) = \theta_1 - I_1 \). The buyer’s net revenues from trading are \( R(\theta_2, I_2) = \theta_2 + I_2 \). The random variables \( \theta_1 \) and \( \theta_2 \) are independently distributed with cumulative distribution functions \( F_1(\theta_1) \) and \( F_2(\theta_2) \), both of which are common knowledge among the divisions and have strictly positive densities, \( f_i(\theta_i) \), over the respective supports \( \Theta_i = [\theta_i, \bar{\theta}_i] \). We denote \( \Theta = [\Theta_1, \Theta_2] \) and \( I = (I_1, I_2) \). In the main part of the paper, neither investments \( I_i \) nor the supports \( \Theta_i \) are assumed verifiable to a corporate controller. This specification seems descriptive for divisions that undertake many different transactions and investments.

Both managers are assumed risk neutral and motivated to maximize the expected profits of their own division.\(^5\) Expected divisional profits in our model consist of expected contribution margins, \( M_i \), less the fixed cost caused by the investment:

\[
\Pi_1 = M_1(\cdot) - w_1(I_1) = \int_{\theta_1} \int_{\theta_2} \left[ t(\theta, I) - (\theta_1 - I_1) \right] q(\theta, I) dF_2(\theta_2) dF_1(\theta_1) - w_1(I_1)
\]

\[
\Pi_2 = M_2(\cdot) - w_2(I_2) = \int_{\theta_1} \int_{\theta_2} \left[ (\theta_2 + I_2) - t(\theta, I) \right] q(\theta, I) dF_2(\theta_2) dF_1(\theta_1) - w_2(I_2)
\]

for the selling and the buying division, respectively. The functions \( (q(\cdot), t(\cdot)) \) are determined by the transfer pricing scheme in place.

Clearly, from the viewpoint of the firm as a whole, the intermediate good should be traded whenever the buyer’s valuation exceeds the seller’s cost:

\[
q^*(\theta, I) = 1 \quad \text{if and only if} \quad \theta_2 + I_2 \geq \theta_1 - I_1.
\]

Equation (1) characterizes the efficient trading rule chosen by the firm in case of complete information and centralized decision making. Denoting by \( E_\theta[\cdot] \) the expectation operator with respect to \( \theta \), we shall assume that \( 0 < E_\theta[q^*(\theta, I)] < 1 \), for all \( I \), to avoid trivial intrafirm transfers. This is equivalent to assuming that the relevant cost and revenue supports intersect for all investments.

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\(^5\) Expected divisional profits in our model consist of expected contribution margins, \( M_i \), less the fixed cost caused by the investment.
Suppose that only the seller can undertake specific investments. The relevant costs and revenues then are given by $C(\theta_1, I_1) = \theta_1 - I_1$ and $R(\theta_2) = \theta_2$. Let first-best expected firm profits as a function of seller investments be denoted by

$$\Pi^*(I_1) = M^*(I_1) - w_1(I_1) = E_0 \left[ (\theta_2 - \theta_1 + I_1) \cdot q^*(\theta, I_1) \right] - w_1(I_1), \quad (2)$$

where $M^*(\cdot) \equiv M_1^*(\cdot) + M_2^*(\cdot)$ and $q^*(\theta, I_1) = 1$ whenever $\theta_2 \geq \theta_1 - I_1$. As a benchmark, we derive the first-best investments by differentiating (2) with respect to $I_1$. By the Envelope Theorem, the necessary first-order condition is

$$w_1'(I_1^*) = \text{Prob}[q^*(\theta, I_1^*) = 1]. \quad (3)$$

The seller should optimally undertake investments up to the point where the marginal cost of investment equals the expected marginal cost savings.

Likewise, if only the buying division invests, then the efficient trading rule, $q^*(\theta, I_2)$, calls for trade if and only if $\theta_2 + I_2 \geq \theta_1$. Efficient buyer investments are determined in a similar fashion as in (2) and (3), with $I_2$ substituting for $I_1$, $w_2(\cdot)$ for $w_1(\cdot)$, and $\Pi^*(I_2)$ for $\Pi^*(I_1)$. The resulting first-order condition is $w_2'(I_2^*) = \text{Prob}[q^*(\theta, I_2^*) = 1].$

(A1) Suppose that only Division $i, i \in \{1, 2\}$, invests. Then the function $\Pi^*(I_i)$ is assumed to be single-peaked with an interior maximizer $I_i^* \in [0, I_i].$

2. The Transfer Pricing Mechanisms

**Standard-cost Transfer Pricing**

Under standard-cost transfer pricing, Manager 1 reports a standard cost number, $t^*$, after he has observed his cost parameter $\theta_1$. The transfer price then equals this cost report which is assumed not to be audited by a corporate controller. The buying division will accept the offer whenever $\theta_2 + I_2 \geq t^*$, which happens with probability $1 - F_2(t^* - I_2)$. Assuming that Manager 1 is not constrained at all, he will act as a profit-maximizing monopolist who faces a customer with an uncertain valuation for the good:

$$t^*(\theta_1, I) = \arg \max \left\{ (t - \theta_1 + I_1) \cdot [1 - F_2(t - I_2)] \right\}.$$

Differentiating this expression with respect to $t$ yields the first-order condition

$$\theta_1 - I_1 = \phi(t^*(\theta_1, I), I_2), \quad \text{(4)}$$

where $\phi(t, I_2) \equiv t - \frac{F_2(t - I_2) - F_2(t - I_2)}{f_2(t - I_2)}$. Manager 1 marks up his true production cost of $\theta_1 - I_1$ by an amount that balances the tradeoff between contribution margin versus the risk of refusal by Manager 2. As is well known from adverse selection models, this amount is determined by the inverse hazard rate of the buyer’s type distribution, $\frac{1 - F_2(t)}{f_2(t)}$. The resulting trading rule under standard-cost transfer pricing becomes:

$$q^*(\theta, I) = 1, \quad \text{if and only if} \quad \theta_2 + I_2 \geq t^*(\theta_1, I). \quad \text{(5)}$$
As in Baldenius, Reichelstein, and Sahay (1999), we note that standard-cost transfer pricing generally leads to inefficient trade, as 

\[ t^s(\theta_1, I) \geq \theta_1 - I. \]

We will extensively deal with uniform distributions, \( F_1 \) and \( F_2 \). The seller’s cost reporting strategy then is:

\[
t^s(\theta_1, I) = \begin{cases} 
\theta_2 + I_2, & \text{if } \theta_1 - I_1 < 2\bar{\theta}_2 - \bar{\theta}_2 + I_2, \\
\frac{1}{2}(\bar{\theta}_2 + \theta_1 - I_1 + I_2), & \text{if } \theta_1 - I_1 \in [2\bar{\theta}_2 - \bar{\theta}_2 + I_2, \bar{\theta}_2 + I_2], \\
\theta_1 - I_1, & \text{if } \theta_1 - I_1 > \bar{\theta}_2 + I_2.
\end{cases}
\]

Our formulation of standard-cost transfer pricing is somewhat extreme in that the selling division faces no direct constraints on its ability to exaggerate cost. However, profit centers are generally engaged in many transactions and often find ways to shift costs across products and services, for instance by allocating overhead costs in a way that burdens the internally transferred good. Our model captures the most common complaint against standard-cost transfer pricing—that the standards are set, or at least influenced, by an interested party in a biased way. Section 5 will relax this assumption.

**Negotiated Transfer Pricing**

As an alternative organizational mode, the firm might let the managers negotiate the terms of the trade. Essentially, this yields a more symmetrical allocation of bargaining power among the divisions. We model the bargaining process as an *equal-split sealed-bid mechanism*, following Chatterjee and Samuelson (1983). Both managers submit sealed bids, and trade occurs if and only if the buyer’s bid, \( b \), exceeds the seller’s bid, \( s \). In this case, the surplus is split equally:

\[ s(\theta_1, I) = \frac{1}{2}(b + s). \]

Manager 1’s bidding strategy, \( s \): \( \Theta_1 \times [0, \bar{T}_1] \times [0, \bar{T}_2] \to \mathbb{R}_+ \), maps “local type information” and observable investments into bids, as does Manager 2’s strategy, \( b \): \( \Theta_2 \times [0, \bar{T}_1] \times [0, \bar{T}_2] \to \mathbb{R}_+ \). In order to derive a Bayesian-Nash equilibrium in linear bidding strategies, we follow Chatterjee and Samuelson in restricting attention to uniform type distributions. The linear bidding strategies solve the following simultaneous optimization problems:

\[
s(\theta_1, I) = \arg\max_s E_{\theta_1} \left[ \frac{s + b(\theta_2, I)}{2} - \theta_1 + I_1 \right] \cdot q^u(\theta, I),
\]

\[
b(\theta_2, I) = \arg\max_b E_{\theta_2} \left[ \left( \theta_2 + I_2 - \frac{s(\theta_1, I) + b}{2} \right) \cdot q^u(\theta, I) \right],
\]

where

\[ q^u(\theta, I) = 1 \quad \text{if and only if} \quad b(\theta_2, I) \geq s(\theta_1, I). \]

We first modify Chatterjee and Samuelson’s (1983) characterization of the Bayesian-Nash equilibrium in linear bidding strategies for the case of up-front investments.

**Lemma 1** Suppose that the divisions’ valuations are uniformly distributed and that the divisions have invested \( I = (I_1, I_2) \). Then the equal-split sealed-bid mechanism yields the
following linear equilibrium bidding strategies:

\[
\begin{align*}
\hat{s}(\theta_1, I) &= \begin{cases} 
\hat{b}(\theta_2, I) = \frac{1}{12}[\theta_2 + 3\theta_1 - 3I_1 + 9I_2 + 8\theta_2]; & \text{if } \hat{s}(\theta_1, I) < \hat{b}(\theta_2, I) \\
& \text{if } \hat{s}(\theta_1, I) = \hat{b}(\theta_2, I) \\
& \hat{s}(\theta_1, I) = \frac{1}{12}[3\theta_2 + \theta_1 - 9I_1 + 3I_2 + 8\theta_1]; & \text{if } \hat{s}(\theta_1, I) > \hat{b}(\theta_2, I)
\end{cases} \\
\theta_1 - I_1, \\
\hat{b}(\theta_2, I) &= \begin{cases} 
\hat{b}(\theta_2, I) = \frac{1}{12}[\theta_2 + 3\theta_1 - 3I_1 + 9I_2 + 8\theta_2]; & \text{if } \hat{b}(\theta_2, I) < \hat{s}(\theta_1, I) \\
& \text{if } \hat{b}(\theta_2, I) = \hat{s}(\theta_1, I) \\
& \hat{b}(\theta_2, I) = \frac{1}{12}[3\theta_2 + \theta_1 - 9I_1 + 3I_2 + 8\theta_1]; & \text{if } \hat{b}(\theta_2, I) > \hat{s}(\theta_1, I)
\end{cases} \\
\theta_2 + I_2,
\end{align*}
\]

(All proofs are contained in Appendix B.)

The upper branches of the strategies apply to situations where trade occurs with certainty. They express the intuitive notion that, say, Manager 1 will never bid less than the lowest equilibrium bid of Manager 2, since this would only reduce the transfer payment without further raising the probability of trade. The lower branches of (10) and (11) characterize situations where the conditional probability of trade is zero.

Both managers tend to shade their offers in that \( s(\theta_1, I) \geq \theta_1 - I_1 \) and \( b(\theta_2, I) \leq \theta_2 + I_2 \). Hence this mechanism is not incentive compatible, and a comparison of (9) with (1) reveals that informational asymmetries give rise to trade inefficiencies under negotiations. This is in stark contrast to Baldenius, Reichelstein, and Sahay’s (1999) symmetric information model where negotiations are always efficient ex post.

Going back to (4), we can reinterpret standard-cost transfer pricing as the outcome of another sealed-bid mechanism, where Manager 2 is “pathologically honest” and Manager 1 optimizes accordingly. Figure 2 depicts the bidding strategies and cost reports under the two mechanisms, given that relevant cost and revenues are uniformly distributed over identical supports, that is, \( \theta_2 - I_1 = \theta_2 + I_2 \) and \( \hat{\theta}_1 - I_1 = \hat{\theta}_2 + I_2 \).

The firm now faces the problem of choosing a transfer pricing mechanism that simultaneously deals with two incentive problems: at the outset, managers should have an incentive to undertake investments and, subsequently, they should be induced to trade the good whenever it is profitable for the firm. The performance comparison is structured along two lines: (i) we analyze settings in which either of the divisions invests, and (ii) within each of these settings, we investigate scenarios where only the seller, only the buyer, or both divisions have private information.

3. Supplier Investments

In this section, we assume that investments by the buying division are unimportant, i.e., \( I_2 \equiv 0 \). The relevant cost and revenues are given by \( C(\theta_1, I_1) = \theta_1 - I_1 \) and \( R(\theta_2) = \theta_2 \). Before addressing the performance comparison between the candidate mechanisms, it is instructive to identify a scenario where one of the schemes, i.e., standard-cost transfer pricing, approaches first-best performance.
If only the supplier invests under standard-cost transfer pricing, then, at date 3, \( q^*(\theta, I_1) = 1 \), if and only if \( \theta_2 \geq t^*(\theta_1, I_1) \), and Manager 1 issues a cost report of

\[
\begin{aligned}
  t^*(\theta_1, I_1) = \\
  \begin{cases}
  \theta_2, & \text{if } \theta_1 - I_1 < \phi(\theta_2), \\
  \phi^{-1}(\theta_1 - I_1), & \text{if } \theta_1 - I_1 \in [\phi(\theta_2), \hat{\theta}_2], \\
  \theta_1 - I_1, & \text{if } \theta_1 - I_1 > \hat{\theta}_2.
  \end{cases}
\end{aligned}
\]  

(12)

where \( \phi(t) \equiv t - \frac{[1 - F_{\epsilon}(\epsilon)]}{F_{\epsilon}(\epsilon)} \). As noted in connection with (5) above, this mechanism leads to inefficient trade, as \( t^*(\theta_1, I_1) \geq \theta_1 - I_1 \).
With regard to investment incentives, standard-cost transfer pricing benefits from the fact that the supplying division receives a large fraction of the total contribution margin owing to its first-mover advantage. The supplier is effectively shielded from hold-up problems when he chooses his investment:

\[ I_1^* \in \arg \max_{I_1} \left\{ E_0[(t'(\theta_1, I_1) - \theta_1 + I_1) \cdot q^*(\theta, I_1)] - w_1(I_1) \right\}. \]

By the Envelope Theorem, the necessary first-order condition is:\(^{12}\)

\[ w_1'(I_1^*) = \text{Prob}(q^*(\theta, I_1^*) = 1). \] (13)

The seller undertakes investments up to the point where the marginal investment costs equal the expected marginal cost savings. Comparing (13) with (3), however, we notice that the cost savings under standard-cost transfer pricing are realized only with lower probability, since

\[ E_0[q^*(\theta, I_1)] \leq E_0[q^*(\theta, I_1)], \]

for all $I_1$. Thus, ex-post trade distortions will diminish divisional investment incentives.

Our first result demonstrates how the buyer’s private information impacts the performance of the cost-based scheme. Let $\Pi^s$ denote the expected firm profit under standard-cost transfer pricing and recall that $\Pi_i \cdot N_{\mu_i}$. Notice further that Proposition 1 holds for general cost and revenue distributions.

**Proposition 1** Suppose that only the supplying division invests under standard-cost transfer pricing. Then $\Pi^s \rightarrow \Pi^*$ as $\Delta_2 \rightarrow 0$.

Recall that the supplier’s pricing problem is determined by a tradeoff between unit contribution margin and the risk of over-bidding. As revenue uncertainty vanishes, $\Delta_2 \rightarrow 0$, the latter effect becomes negligible, and Manager 1 can bid more aggressively. Formally, $\phi(\theta_2) \rightarrow \theta_2^*$, and the middle branch in (12) evaporates. The supplying division can perfectly extract the contribution margin, and its investments are shielded from hold-up problems. Hence, it fully internalizes the firm-wide objective. Put differently, since there are no incentive problems associated with the buying division, it is desirable to allocate residual profits to the seller.\(^{13}\) In general, the performance of standard-cost transfer pricing degrades when the supplier has coarser information about the buyer’s valuation, because the transfer price is based on the supplier’s information only and hence lacks the flexibility to reflect different realizations of $\theta_2$.

The discrete nature of the trading problem is crucial for Proposition 1 to hold. In Baldeynius, Reichelstein, and Sahay (1999), in contrast, the quantity variable is continuous but the supplier is constrained to linear pricing. Thus, standard-cost transfer pricing remains inefficient even though the supplier knows the buyer’s willingness-to-pay.

Under negotiated transfer pricing, the bidding strategies are obtained by setting $I_2 = 0$ in Lemma 1. In particular, notice that Manager 2’s strategy, $b: \Theta_2 \times [0, T_1] \rightarrow R_+$, is contingent on $I_1$. This will give rise to hold-up problems as demonstrated below.

For the following performance comparison, we shall confine attention to uniform parameter distributions. Let $\theta_i \sim U[\bar{\theta}_i, \bar{\theta}_i]$ denote that $\theta_i$ is uniformly distributed over the interval $[\bar{\theta}_i, \bar{\theta}_i]$. The previous discussion has shown that some transfer pricing schemes may be “vulnerable” only with respect to certain kinds of uncertainty: for Proposition 1
to hold, the supplier’s cost parameter \( \theta_1 \) may be highly uncertain, as long as \( \theta_2 \) is known. To capture this, we will consider the following informational scenarios (the variable \( I_2 \) for buyer investments is included for later reference in Section 4):

(CU) One-sided Cost Uncertainty is characterized by \( \theta_1 \sim U[0,1] \) and \( \theta_2 \sim U[\theta_2^o, \theta_2 + \Delta_2] \), where \( \Delta_2 \) is “small,” and \( \theta_2 \subset (0, 1 - (\tilde{T}_1 + T_2)) \).

(BU) Bilateral Uncertainty is characterized by \( \theta_i \sim U[\theta_i^o, \tilde{\theta}_i] \) where both \( \Delta_i > 0 \), with \( \tilde{\theta}_2 \geq \theta_1 \geq \frac{3}{4} \tilde{\theta}_2 + \frac{1}{4} \tilde{\theta}_1 + \frac{3}{4}(T_1 + T_2) \) and \( \tilde{\theta}_1 \leq \theta_2 \leq \frac{1}{4} \tilde{\theta}_2 + \frac{3}{4} \tilde{\theta}_1 - \frac{3}{4}(T_1 + T_2) \).

(RU) One-sided Revenue Uncertainty is characterized by \( \theta_2 \sim U[0,1] \) and \( \theta_1 \sim U[\theta_1^o, \theta_1^o + \Delta_1] \), where \( \Delta_1 \) is “small,” and \( \theta_1 \subset (\tilde{T}_1 + T_2, 1) \).

These scenarios are mutually exclusive, but not commonly exhaustive. Focusing on these cases allows us to identify the main tradeoffs associated with the two transfer pricing schemes.

Cost Uncertainty describes the uniform distribution version of the scenario considered in Proposition 1. Bilateral Uncertainty is a weaker condition than identical valuation supports; it holds if the valuation supports differ to a limited extent. The one-sided uncertainty cases imply that the trading problems under standard-cost transfer pricing converge to one-sided private information settings where the take-it-or-leave-it offer is made by the informed manager (Cost Uncertainty) or by the uninformed one (Revenue Uncertainty). For the remainder of Section 3, we shall again assume that \( I_2 = 0 \).

Cost Uncertainty—(CU)

If only the supplying division has private information, Proposition 1 has shown that standard-cost transfer pricing converges toward first-best. Under negotiated transfer pricing, the bidding strategies given in Lemma 1 converge to

\[
\begin{align*}
\bar{b}(\theta_2^o, I_1) &= \frac{3}{4} \theta_2^o - \frac{1}{4} I_1 \\
s(\theta_1, I_1) &= \max\left\{ b(\theta_2^o, I_1), \theta_1 - I_1 \right\}
\end{align*}
\]

as \( \Delta_2 \to 0 \). Hence, in the limit, both managers know \( \theta_2^o \), yet Manager 2 shades his bid, and gains from trade are lost. Essentially, the buyer’s bargaining power results in both managers settling on a price which is the buyer’s reservation price less a discount, and the buyer earns a strictly positive contribution margin, \( \theta_2^o - b(\theta_2^o, I_1) \), if trade occurs.

Both bidding strategies under negotiations are contingent on \( I_1 \). In particular, (14) implies that \( \frac{\partial b}{\partial I_1} = -\frac{1}{4} \). As \( I_1 \) increases, the buyer captures a share of the additional contribution margin by lowering his bid. The supplier’s investment problem is:

\[
I_1^u \in \arg\max_{I_1} \left\{ \int_0^{b(\theta_2^o, I_1) + I_1} \left[ b(\theta_2^o, I_1) - \theta_1 + I_1 \right] \frac{1}{\Delta_1} d\theta_1 - w_1(I_1) \right\}.
\]
Differentiating this term with respect to $I_1$ yields

$$w'_i(I^n_1) = \left(1 + \frac{\partial b(\theta^n_1, I^n_1)}{\partial I_1} \right) \cdot \text{Prob}[q^n(\theta, I^n_1) = 1]$$

$$= \frac{3}{4} \text{Prob}[q^n(\theta, I^n_1) = 1]. \quad (15)$$

Equation (15) reveals that negotiated transfer pricing suffers from underinvestment for two reasons: first, since $\text{Prob}[q^n(\theta, I_1) = 1] < \text{Prob}[q^n(\theta, I_1) = 1]$, for all $I_1$, the cost reduction is realized only with lower probability and, secondly, the hold-up problem due to $\frac{\partial b(\cdot)}{\partial I_1} = -\frac{1}{2}$ further degrades investment incentives. We denote by $\Pi^n$ the expected firm profit under negotiated transfer pricing.\(^{16}\)

**Proposition 2** Suppose (A1) holds and there is only Cost Uncertainty (i.e., (CU) holds). If only the supplying division invests, negotiated transfer pricing is dominated by standard-cost transfer pricing. Formally, $\lim_{\Delta_2 \to 0} \Pi^n < \lim_{\Delta_2 \to 0} \Pi^t$.

Our results pertaining to the performance comparison are summarized in Table 1 below. Negotiated transfer pricing suffers from two deficiencies. First, for any investment $I_1$, $M^n(I_1) < M^s(I_1)$, due to the discount demanded by the buyer. For some realizations of $\theta$, negotiations will not lead to an intrafirm transfer even though trade would be efficient. Secondly, negotiated transfer pricing suffers from underinvestment as described above. Both these deficiencies generalize to all three informational cases: as long as there is private information associated with at least one division’s type distribution and the supports intersect, negotiations suffers from trade distortions and hold-up problems.

**Bilateral Uncertainty—(BU)**

When the firm adopts negotiated transfer pricing under Bilateral Uncertainty, then only the lower two branches of the bidding strategies in (10) and (11), respectively, can occur. Again, by (11), Division 2 will lower its bid, the higher the seller’s investments: $\frac{\partial b}{\partial I_1} = -\frac{1}{2}$, for each $\theta_2, I_1$, provided the conditional probability of trade is strictly positive. Manager 1 then chooses $I^n_1$ so as to maximize

$$\int_{\theta_2}^{b(\theta_2, I_1) + I_1} \int_{b^{-1}(s(\theta_2, I_1), I_1)}^{\theta_2} \left[b(\theta_2, I_1) + s(\theta_2, I_1) \right. \bigg/ 2 \left. - \theta_1 + I_1 \right] dF_2(\theta_2) dF_1(\theta_1) - w_1(I_1),$$

where $b^{-1}(s(\theta_1, I_1), I_1) = \theta_1 + \frac{1}{2}(\tilde{\theta}_2 - \hat{\theta}_1 - 3I_1)$, is the lowest realization of $\theta_2$ such that trade occurs, conditional on $\theta_1$ and $I_1$.\(^{17}\) The transfer payment, as the average of the two bids, is a function of $I_1$. The necessary first-order condition for an optimum $I^n_1$ is

$$w'_i(I^n_1) = \left[1 + \frac{1}{2} \left( \frac{\partial b(\cdot)}{\partial I_1} + \frac{\partial s(\cdot)}{\partial I_1} \right) \right] \cdot \text{Prob}[q^n(\theta, I^n_1) = 1]$$

$$- \int_{\theta_2}^{b(\theta_2, I^n_1) + I^n_1} \left[ \frac{\partial b^{-1}(\cdot)}{\partial I_1} \cdot (s(\theta_2, I^n_1) - (\theta_1 - I_1^n)) \frac{1}{\Delta_1 \Delta_2} \right] d\theta_2. \quad (16)$$
After some simplifications, this condition becomes

$$w_0^* = \frac{3}{4} \text{Prob}[q^n(\theta, I^n_1) = 1]. \quad (17)$$

Under negotiated transfer pricing, we find that the supplier’s investment incentives are reduced by the hold-up term \( \frac{dt}{d\theta} = \frac{3}{4} \left[ \frac{d\theta}{d\theta} + \frac{d\theta}{d\theta} \right] = -\frac{1}{2}. \) However, now there is an additional positive first-order effect arising from an expansion of the set \( \{q^n(\theta, I_1) = 1\} \), as expressed in the second line in (16). The reason for this is that for the cutoff value \( s^{-1}(b(\theta_2, I_1), I_1) \) the supplier would derive a strictly positive contribution margin if trade occurred.

We are now in a position to compare the performance of the transfer pricing schemes given that both divisions have private information.

**Proposition 3** Suppose that only the supplying division invests under Bilateral Uncertainty (i.e., (BU) holds). Then:

i. Negotiated transfer pricing achieves higher expected contribution margins: \( M^n(I_1) > M^s(I_1) \), for all \( I_1 \);

ii. Standard-cost transfer pricing generates better investment incentives: \( I^s_1 > I^n_1 \).

Proposition 3 implies that the overall profitability comparison is indeterminate: the firm faces a tradeoff between higher investments under standard-cost transfer pricing versus more efficient trade under negotiations. The second part of the result is driven by the fact that the seller’s marginal return from investing is uniformly higher under standard-cost transfer pricing. Formally, a comparison of (13) with (17) reveals that, for all \( I_1 \),

$$\text{Prob}[q^n(\theta, I^n_1) = 1] > \text{Prob}[q^s(\theta, I^n_1) = 1] > \frac{3}{4} \text{Prob}[q^n(\theta, I^s_1) = 1].$$

The first part of Proposition 3 is worth relating to Myerson and Satterthwaite’s (1983) work on optimal trading mechanisms. Myerson and Satterthwaite observe that the symmetrical sealed-bid mechanism is outcome-equivalent to an optimal revelation mechanism, if the types are uniformly and symmetrically distributed. Essentially, a mechanism is optimal, if the least favorable types just break even in expectation, and if both divisions’ objectives are given equal weight. Since the standard-cost transfer payment is not contingent on the buyer’s type realization, the latter symmetry requirement cannot be met by this scheme. We demonstrate this lack of flexibility by showing how the transfer payments under Bilateral Uncertainty are affected by changes in the types:

$$\frac{dt^n}{d\theta_1} = \frac{\partial t^n}{\partial s} \frac{\partial s}{\partial \theta_1} = \frac{1}{3} < \frac{dt^s}{d\theta_1} = \frac{1}{2},$$

while

$$\frac{dt^n}{d\theta_2} = \frac{\partial t^n}{\partial b} \frac{\partial b}{\partial \theta_2} = \frac{1}{3} > \frac{dt^s}{d\theta_2} = 0.$$
The negotiated transfer payment is equally contingent upon both type realizations, but less sensitive than under cost-based pricing with respect to changes in $\mu_1$. Our result shows that, although negotiated transfer pricing leads to suboptimal trade if the supports differ, this system still outperforms a regime where one division makes a take-it-or-leave-it offer. Put differently, even though $\mu_2$ enters the negotiated transfer payment in a biased way, the firm still wants this information to be incorporated.

**Revenue Uncertainty—(RU)**

If the supplying division’s cost is “almost” known to the buyer, as postulated by (RU), then the bidding strategies derived in Lemma 1 converge to $s(\theta^o, I_1) = \frac{3}{4} + \frac{1}{4} \theta^o - \frac{1}{4} I_1$ and $b_t(\theta_2, I_1) = \min\{s(\theta^o, I_1), \theta_2\}$, as $\Delta_1 \to 0$. The supplying division will mark up its actual cost by an amount equal to $s(\theta^o, I_1) - (\theta^o - I_1) = \frac{1}{4}(1 - \theta^o + I_1)$. This represents its contribution margin if trade occurs. The seller’s investment problem now becomes

$$I^n_1 \in \arg \max_{I_1} \left\{ \frac{1}{4} (1 - \theta^o + I_1) \cdot [1 - F_2(s(\theta^o, I_1))] - w_1(I_1) \right\}.$$  

The corresponding first-order condition is

$$w'_1(I^n_1) = \frac{1}{2} \text{Prob}[q^n(\theta, I^n_1) = 1]. \quad (18)$$

Thus, the supplier’s investment incentives under negotiated transfer pricing are particularly weak as $\Delta_1 \to 0$. Comparing (15) and (17) with (18) yields an important qualitative observation that is reflected in Table 4 in Appendix A: Hold-up problems tend to diminish with private information on the part of the investing division.

Comparing the performance of the two transfer pricing schemes, we encounter a similar tradeoff as in Proposition 3: standard-cost transfer pricing induces higher investments but less efficient trade compared with negotiated transfer pricing. For the simple case of a quadratic investment cost function, the trade effect can be shown to dominate the investment effect.

**Proposition 4** Suppose (A1) holds, $w_1(I_1) = \frac{1}{2} I^n_1$ and there is one-sided Revenue Uncertainty (i.e., (RU) holds). If only the supplying division invests, then negotiated transfer pricing dominates standard-cost transfer pricing, as $\Delta_1 \to 0$.

The intuition for this result is that, with a quadratic cost function, the difference $I^n_1 - I^n_1$ is too small to make the investment effect dominate the trade effect.

### 4. Buyer Investments

We begin this section by assuming that seller investments are unimportant, i.e. $I_1 = 0$, while the buying division may raise its net revenues by undertaking specific investments. Accordingly, we will speak of the induced “relevant revenue distribution” defined over $\Theta_2 \times$
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[0, \hat{T}_2] with support \{\bar{\theta}_2 + I_2, \tilde{\theta}_2 + I_2\} for given \(I_2\). Under both transfer pricing mechanisms, the supplying division’s bidding, or cost reporting, strategies will now depend on \(I_2\). This gives rise to hold-up problems under both mechanisms. As demonstrated in the previous section, hold-up problems are driven by the distribution of bargaining power. Whereas the seller’s investments were perfectly shielded under standard-cost transfer pricing, we would now expect this regime to entail more severe hold-up problems than negotiated transfer pricing. This intuition will indeed be confirmed below.

Under negotiations, the divisions’ bidding strategies are obtained by setting \(I_1 = 0\) in Lemma 1. Manager 1’s cost report issued under cost-based transfer pricing equals

\[
t^*(\theta, I_2) = \begin{cases} 
\bar{\theta}_2 + I_2, & \text{if } \theta_1 < 2\bar{\theta}_2 - \tilde{\theta}_2 + I_2, \\
\frac{1}{2}(\hat{\theta}_2 + \theta_1 + I_2), & \text{if } \theta_1 \in [2\bar{\theta}_2 - \tilde{\theta}_2 + I_2, \tilde{\theta}_2 + I_2], \\
\hat{\theta}_1, & \text{if } \theta_1 > \hat{\theta}_2 + I_2.
\end{cases}
\] (19)

which is obtained by rewriting (12) for the case of uniform type distributions. The respective trading rules are \(q^n(\theta, I_2) = 1\) whenever \(b(\hat{\theta}_2, I_2) \geq s(\theta_1, I_2)\), and \(q^*(\theta, I_2) = 1\) whenever \(\hat{\theta}_2 + I_2 \geq t^*(\theta_1, I_2)\).

**Cost Uncertainty—(CU)**

If Division 2’s revenues become known to the supplying division, then the latter division can extract the entire surplus under standard-cost transfer pricing. Obviously, this makes the buying division unwilling to invest at all, so that \(I_2 = 0\). This drastically illustrates our previous observation that private information plays a crucial role as an investment shield.

Under negotiated transfer pricing, the buying division’s investment incentives resemble the seller’s incentives under Revenue Uncertainty as given in (18). Hence, the firm faces a tradeoff between positive investment under negotiations versus ex-post efficiency under standard-cost transfer pricing. Depending on the functional form of \(w_2(I_2)\), either effect may dominate.

**Bilateral Uncertainty—(BU)**

Under standard-cost transfer pricing, Manager 1 will charge a transfer payment of \(t^*(\theta_0, I_2) = \frac{1}{2}(\bar{\theta}_2 + \theta_1 + I_2)\) at the trading stage, provided Bilateral Uncertainty prevails. We notice that \(\frac{\partial t^*(\theta_0, I_2)}{\partial I_2} = \frac{1}{2}\). In light of this severe hold-up problem, the buyer’s investment satisfies the first-order condition

\[
w_2(I_2) = \frac{1}{2} \text{Prob}\{q^*(\theta, I_2) = 1\}.
\] (20)

Under negotiated transfer pricing, the buying division’s investment incentives are determined in a similar fashion as in (17), which yields the first-order condition \\

Comparing this with (20) suggests that $I_n^2 > I_s^2$. To conduct the profit comparison, however, we require a technical condition on the profit function under negotiated transfer pricing. We define the following:

$$\Pi^n(I_2) = \int_{\theta_1} \int_{\theta_2} \left( \theta_2 + I_2 - \theta_1 \right) q^n(\theta_1, I_2) dF_1(\theta_1) dF_2(\theta_2) - w_2(I_2).$$

(A2) The function $\Pi^n(I_2)$ is single-peaked with an interior maximizer $\hat{I}_n^2 \in (0, T_2).$

**Proposition 5** Suppose (A1) and (A2) hold and there is Bilateral Uncertainty (i.e. (BU) holds). If only the buying division invests, then negotiated transfer pricing dominates standard-cost transfer pricing.

Proposition 5 reflects that negotiated transfer pricing yields both higher investments and greater expected contribution margins for all investments. This result and the underlying intuition extend to situations of one-sided Revenue Uncertainty.

**Bilateral Investments**

How do the above findings generalize to situations where both divisions have investment opportunities? Clearly, the divisional investment decisions are interdependent: high values of $I_1$ raise the probability of trade and hence raise Division 2’s incentive to invest, as well. This might suggest that if, say, $I_n^2(I_1) \gg I_s^2(I_1)$, for all $I_1$, then this strategic complementarity could also induce the seller to invest more under negotiated than under standard-cost transfer pricing. For the case of quadratic investment costs, however, this strategic effect turns out to be too weak to overcome the hold-up problem, so that $I_s^1 > I_n^1$ and $I_s^2 < I_n^2$ can be shown to hold in equilibrium.

To examine this point in more detail, notice that the dual role of private information—as source of trade distortions and as investment shield—has countervailing investment effects. Under one-sided Revenue Uncertainty, for instance, trade efficiency considerations call for negotiated transfer pricing since $\text{Prob}(q^n(\theta, I_1) = 1) > \text{Prob}(q^s(\theta, I_1) = 1)$ for all $I_1$. That is, the firm-wide marginal investment returns are higher under negotiated transfer pricing. In comparison with the cost-based scheme, however, negotiations shift bargaining power from Manager 1—who is very vulnerable to hold-up problems—to Manager 2 whose investments are partly shielded by private information. Thus total hold-up problems are exacerbated while the probability of trade increases. The net effect generally remains ambiguous.

Table 1 summarizes the results obtained for the one-sided investment cases and highlights the main themes of this paper. Recall that $M$ denotes expected firm-wide contribution margin, $\Pi$ denotes expected profit and the superscripts $n$ and $s$ denote negotiated and standard-cost transfer pricing, respectively.

By pair-wise comparison of the last two cells in each column, we find that the performance of standard-cost transfer pricing degrades when investments by the buying division are essential. For all informational scenarios considered in our analysis, $I_s^1 > I_n^1$ and $I_s^2 < I_n^2$ both hold. This confirms the intuition obtained from symmetric information.
models that hold-up problems will be mitigated if the investing division is given more bargaining power (Grossman and Hart, 1986). Secondly, by comparing the cells in any of the rows in Table 1, we find that bargaining power should be conferred to the division that has “more” private information in order to reduce trade distortions. In agency-theoretic terms: if only one division has private information, then this division should be made the principal—i.e., given all contracting power—rather than letting both divisions negotiate.

5. Centralized Transfer Pricing

The preceding analysis was built on the assumption that the center for a corporate controller in general has less information about Division i’s operations—on a disaggregated product line level—than has Division j which is trading this product with Division i. When choosing a transfer pricing scheme, the center was assumed to know only which of the divisions had an investment opportunity and whether the setting was one of cost and/or revenue uncertainty. In such a setting there is a natural demand for decentralization simply due to lack of centrally held information. While this seems descriptive for large diversified companies, in this section we shall modify this scenario by assuming that the corporate controller knows the seller’s cost support, \( \theta_1 \).

Suppose only the supplying division has an investment opportunity. To avoid hold-up problems, suppose also that the central office can commit to a transfer price, \( t \), before investments are undertaken. For any \( t, I_1 \) and \( \theta \), the trading rule becomes

\[
q(t, \theta, I_1) = 1, \quad \text{if and only if} \quad \theta_2 \geq t \geq \theta_1 - I_1.
\]

If the center is assumed to know \( \theta_1 \), then it is reasonable to assume that it also knows \( \theta_2 \). Setting \( t \) equal to expected cost then turns out to be suboptimal. The optimal centralized ex-ante transfer price, \( t^c \), under Bilateral Uncertainty (BU) instead solves:

Program I:

\[
t^c \in \arg \max_t \left\{ \max_{\theta_1} \int_{\min(t, \theta_2)}^{\theta_1} \int_{I_1}^{I_1 + I_1} \left[ \theta_2 - \theta_1 + I_1 \right] f_2(\theta_2) f_1(\theta_1) d\theta_2 d\theta_1 - w_1(I_1) \right\}, \quad (21)
\]
subject to

\[
I_i \in \arg \max_{I_i} \left\{ \int_{\theta_1}^{\theta_2} \int_{\min(t, \theta_2)}^{\theta_2} \left[ I - \theta_1 + I_i \right] f_2(\theta_2) f_1(\theta_1) d\theta_2 d\theta_1 - w_1(I_i) \right\}, \quad (IC)
\]

The transfer price maximizes the expected firm profit, given that the supplying division will subsequently choose its investment so as to maximize its own expected divisional profit, as expressed by the investment constraint (IC). As a technical prerequisite, we impose a condition that ensures that all investment problems are concave:

\[(A3) \quad \text{For all } I_i, w_i^*(I_i) > \frac{1}{2\Delta_2}(\bar{\theta}_2 - \bar{\theta}_1 + I_i).\]

In the Appendix, it is shown that the solution to Program I can be expressed as \(t^c = \frac{1}{2}(\bar{\theta}_2 - I_1(t^c) + \bar{\theta}_1)\), with \(I_1(t^c)\) denoting the solution to (IC), given \(t = t^c\). Since \(\bar{\theta}_2 \geq \bar{\theta}_1\) holds by (BU), the optimal centralized transfer price takes the form of standard-cost-plus-mark-up: \(t^c = \left[E[\theta_1] - I_1(t^c)\right] + m\), where the mark-up is given by \(m = \frac{1}{2}(\bar{\theta}_2 - \bar{\theta}_1 + I_1(t^c))\). While mark-ups are commonly observed in practice, our model provides a new rationale for this practice: in a discrete quantity setting with bilateral private information, the optimal mark-up over expected cost trades off the risks of refusal by the two divisions and actually enhances trade efficiency.24

We first conduct a performance comparison between this centralized mechanism and standard-cost transfer pricing, as defined in previous sections, for the case of seller investments. Let the expected firm profit achieved under Program I be denoted by \(\Pi^c\).

**Proposition 6** Suppose (A3) and (BU) hold and the corporate controller knows the parameter ranges \((\Theta_1, \Theta_2)\). If only the supplying division invests, then centralized transfer pricing dominates standard-cost transfer pricing: \(\Pi^c > \Pi^s\).

A similar result can be established for buyer investments where the case for centralization is even more pronounced due to avoided hold-up problems. According to Proposition 6, the firm can indeed improve upon the performance of cost-based transfer pricing by centralizing the standard-setting process and employing a suitable mark-up, given that the corporate controller is endowed with sufficient information.

The natural question now is whether such a centralized mechanism outperforms negotiated transfer pricing, as well. Proposition 7 demonstrates that this performance comparison remains indeterminate (with \(M^e(I_1, t)\) denoting the contribution margin component of the objective function in (21), for any arbitrary values \(I_1\) and \(t\)).

**Proposition 7** Suppose (A3) and (BU) hold and the corporate controller knows the parameter ranges \((\Theta_1, \Theta_2)\). If only the supplying division invests, then:

i Negotiated transfer pricing achieves higher expected contribution margins than centralized transfer pricing: \(M^n(I_1) > M^e(I_1, t)\), for all \(t\) and \(I_1\);

ii Centralized transfer pricing generates higher investments: \(I^c_1 > I^n_1\).
Table 2. Optimal mark-ups and trade efficiency for $I_1 = I_2 = 0$.

<table>
<thead>
<tr>
<th>Cost Uncertainty</th>
<th>Bilateral Uncertainty</th>
<th>Revenue Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m$</td>
<td>$m = \theta_1^c - E[\theta_1]$</td>
<td>$m = \frac{1}{2}(\theta_2 - \theta_1)$</td>
</tr>
<tr>
<td>$M^i$</td>
<td>$M^* &lt; \min{M^i, M^s} \to M^*$</td>
<td>$M^s &lt; M^i &lt; M^* \otimes M^*$</td>
</tr>
<tr>
<td>$M^i$</td>
<td>$M^* &lt; M^s &lt; M^* \otimes M^*$</td>
<td></td>
</tr>
</tbody>
</table>

A similar result holds for buyer investments. Due to the flexibility with regard to both divisions’ parameter realizations, negotiations still achieve the highest trade efficiency of all mechanisms considered, despite the fact that divisions bid strategically. The centralized mechanism, on the other hand, avoids hold-up problems and, therefore, induces higher investments.

The optimal mark-up, $m$, proves to be a flexible instrument facilitating first-best trade efficiency whenever one of the type distributions converges. We demonstrate this for the case of $I_1 = I_2 = 0$: if $\Delta_1 \to 0$ (condition (RU)), then the firm sets $m = 0$ yielding $t^* = \theta^c_1$; whereas under one-sided cost uncertainty (CU), $m = \theta^c_2 - E[\theta_1]$ so that $t^* = \theta^c_2$ in fact becomes a net-revenue-based transfer price (technically, $m$ may be negative). In both these cases, $t$ is chosen so as to shift residual profits to that division whose parameter is subject to uncertainty. Table 2 summarizes these findings.

It is worth stressing that the profit-enhancing role for centralizing the transfer pricing process crucially hinges on the central office’s knowing the parameter ranges $\Theta_1$ and $\Theta_2$. This assumption is much stronger than the one underlying our basic model where we have assumed that the center is even more “remote” from Division $i$’s operating activities, on a product line level, than is Division $j$.

6. Concluding Remarks

In the preceding analysis, private information and the need for up-front investments jointly determine a firm’s preference for alternative transfer pricing mechanisms, given that the center lacks precise information to set a realistic transfer price itself. One empirical implication of our results is that standard-cost transfer pricing should be observed in cases where the supplier makes cost-reducing investments and faces little uncertainty with respect to the buying division’s revenues. In most other cases, however, negotiated transfer pricing tends to dominate, either because more efficient intrafirm transfers offset the disadvantage from hold-up problems, or because negotiated transfer pricing is superior in both dimensions: investment and intrafirm transfers.

Our model is stylized in several respects. First, negotiations in practice proceed sequentially, rather than as a sealed-bid mechanism. Trade inefficiencies may then be reduced at the cost of interdivisional haggling. Also, under standard-cost transfer pricing, the supplier will generally be constrained in his reporting behavior as the accounting system will be able to detect over-reporting if it exceeds some bound. Such partial verifiability of standard costs will improve the realized contribution margin for given investments at the expense of diminished investment incentives for the seller (Sahay, 1997; Baldeunis, Reichelstein and Sahay, 1999).
Throughout our analysis, we have viewed the managers’ information as exogenous. Through organizational design, however, the firm may be able to affect the informational environment. For instance, job rotations across divisions will enhance inter-divisional information transmission. Taking investment incentives into account, this will not always be desirable. For instance, if only the buyer invests under standard-cost transfer pricing, then one can construct examples where the firm prefers the buyer to have private information, despite the attendant trade distortions. This is because private information ensures positive investment. In fact, both divisions may benefit from private information on the part of the buyer. So, even if the seller could observe the buyer’s revenues, he may want to commit not to use this information in order to induce the buyer to invest. Such commitment power, however, seems difficult to achieve.25

Our performance comparison has been confined to negotiated and standard-cost transfer pricing. Frequently, the intermediate good can be traded in imperfectly competitive external markets, and the firm may then consider market-based transfer pricing as a third alternative. The presence of external markets also affects negotiated transfer pricing since the bargaining outcome may depend on the divisions’ “outside options.” It would advance the applied theory of transfer pricing if future research could assess the relative strength of all different mechanisms that are reported to be commonly used by companies.

Acknowledgments

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Appendix

A Bidding Strategies and Investment Incentives

In Table 3 we summarize the divisions’ bidding strategies under the transfer pricing schemes, provided one-sided uncertainty prevails with $\Delta_i \to 0$. Table 4 contains the marginal investment returns for all informational scenarios and illustrates the role of private information as an investment shield.

B Proofs

Proof of Lemma 1: We follow Chatterjee and Samuelson (1983) in deriving the linear-strategy Bayesian-Nash equilibrium under negotiated transfer pricing.

For given $I$, let $\tau_1 \equiv \theta_1 - I_1$, and $\tau_2 \equiv \theta_2 + I_2$ denote the relevant divisional costs and revenues. The corresponding support boundaries are $\tau_{1l} \equiv \theta_{1l} - I_1$, $\tau_{1r} \equiv \theta_{1r} - I_1$, $\tau_{2l} \equiv \theta_{2l} + I_2$, and $\tau_{2r} \equiv \theta_{2r} + I_2$. 


and by (ii) the bidding strategies 
\[ s(\theta^o, \theta, \theta_1 - \theta_1), \ s(\theta^o, \ I, \ I) = \frac{1}{2}(1 + 3\theta^o_2 - 4\theta^o_1 + I_2) \]
\[ b(\theta^o, \ I) = \frac{1}{4}(3\theta^o_2 - I_1 + 3I_2) \]
\[ b(\theta, \ I) = \min(s(\theta^o, \ I), \theta_2 + I_2) \]
\[ r^*(\theta, \ I) = \max(\theta^o_2 + I_2, \theta_1 - \theta_1) \]
\[ r^*(\theta^o, \ I) = \frac{1}{2}(1 + \theta^o_2 - I_1 + I_2) \]

Table 3. Bidding and cost reporting strategies.

<table>
<thead>
<tr>
<th>Cost Uncertainty</th>
<th>Revenue Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>(s(\theta, \ I) = \max(b(\theta^o, \ I), \theta_1 - \theta_1))</td>
<td>(s(\theta^o, \ I) = \frac{1}{2}(1 + 3\theta^o_2 - 4\theta^o_1 + I_2))</td>
</tr>
<tr>
<td>(b(\theta^o, \ I) = \frac{1}{4}(3\theta^o_2 - I_1 + 3I_2))</td>
<td>(b(\theta, \ I) = \min(s(\theta^o, \ I), \theta_2 + I_2))</td>
</tr>
<tr>
<td>(r^*(\theta, \ I) = \max(\theta^o_2 + I_2, \theta_1 - \theta_1))</td>
<td>(r^*(\theta^o, \ I) = \frac{1}{2}(1 + \theta^o_2 - I_1 + I_2))</td>
</tr>
</tbody>
</table>

Table 4. Marginal divisional investment returns.

<table>
<thead>
<tr>
<th>Cost Uncertainty</th>
<th>Bilateral Uncertainty</th>
<th>Revenue Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M_1^o(I_1) = \frac{1}{2} \text{Prob}[q^*(\theta, \ I_1) = 1] )</td>
<td>(M_2^o(I_1) = \frac{1}{2} \text{Prob}[q^*(\theta, \ I_1) = 1] )</td>
<td>(M_3^o(I_1) = \frac{1}{2} \text{Prob}[q^*(\theta, \ I_1) = 1] )</td>
</tr>
<tr>
<td>(M_1^o(I_2) = \frac{1}{2} \text{Prob}[q^*(\theta, \ I_2) = 1] )</td>
<td>(M_2^o(I_2) = \frac{1}{2} \text{Prob}[q^*(\theta, \ I_2) = 1] )</td>
<td>(M_3^o(I_2) = \frac{1}{2} \text{Prob}[q^*(\theta, \ I_2) = 1] )</td>
</tr>
</tbody>
</table>

\[
\tau_2 = \theta_2 - I_2, \quad \bar{\tau}_2 = \bar{\theta}_2 - I_2. \quad \text{This induces (uniform) distributions } \tilde{F}_1(\tau_1), \text{ defined over } [\tau_2, \bar{\tau}_2]. \quad \text{Now restate the maximization problems as given in (7) and (8):}
\]

\[
\hat{s}(\tau_1, I) = \arg \max_{\hat{s}} \int_{\hat{s}}^b \left[ \frac{1}{2}(b + s) - \tau_1 \right] dG_2(b, I), \quad \hat{b}(\tau_2, I) = \arg \max_{\hat{b}} \int_{\hat{b}}^b \left[ \tau_2 - \frac{1}{2}(b + s) \right] dG_1(s, I).
\]

The bid distribution functions \(G_i\) are induced by (i) the underlying type distributions \(F_i(\tau_i)\), and by (ii) the bidding strategies \(\hat{s}\) and \(\hat{b}\), where \(G_1(\xi, I) = \hat{F}_1(\hat{s}^{-1}(\xi, I))\) and \(G_2(\xi, I) = \hat{F}_2(\hat{b}^{-1}(\xi, I))\). The first-order condition for the seller is

\[
\frac{1}{2}[1 - G_2(\hat{s}(\cdot, I)) - (\hat{s}(\cdot) - \tau_1) \cdot g_2(\hat{s}(\cdot), I) = 0,
\]

with \(g_i\) denoting the density function to \(G_i\). Defining \(x = \hat{b}^{-1}(\hat{s}, I)\), we have \(g_2(\hat{s}, I) = f_2(x)/\hat{b}'(x, I)\), \(\tau_1 = \hat{s}^{-1}(\hat{b}(x, I), I)\), and \(G_2(\hat{s}, I) = F_2(x)\), and the first-order condition can be restated as

\[
\hat{s}^{-1}(\hat{b}(x, I), I) = \hat{b}(x, I) - \frac{1}{2} \hat{b}'(x, I) \frac{1 - \hat{F}_2(x)}{\hat{f}_2(x)}.
\]

Proceeding in a similar fashion for the buyer yields

\[
\hat{b}^{-1}(\hat{s}(y, I), I) = \hat{s}(y, I) + \frac{1}{2} \hat{s}'(y, I) \frac{\hat{F}_1(y)}{\hat{f}_1(y)},
\]
where \( \gamma \equiv \hat{s}^{-1}(\hat{b}, I) \). A Bayesian-Nash equilibrium now is a solution to these two linked differential equations. Restricting attention to linear bidding strategies \( \hat{s}(\tau_1, I) = \alpha_1(I) + \beta_1(I) \cdot \tau_1 \) and \( \hat{b}(\tau_2, I) = \alpha_2(I) + \beta_2(I) \cdot \tau_2 \), we have

\[
\hat{s}^{-1}(\hat{b}(\tau_2, I), I) = \hat{b}(\tau_2, I) - \frac{1}{2} \beta_2(I) \cdot (\hat{\tau}_2 - \tau_2),
\]

\[
\hat{b}^{-1}(\hat{s}(\tau_1, I), I) = \hat{s}(\tau_1, I) + \frac{1}{2} \beta_1(I) \cdot (\tau_1 - \hat{\tau}_1).
\]

By differentiation, we can determine the slopes of the strategies, which turn out to be independent of \( I \): \( \beta_1 = \beta_2 = \frac{2}{\gamma} \). It follows that the intercept terms are \( \alpha_1 = \frac{1}{4} \hat{\tau}_2 + \frac{1}{12} \hat{\tau}_1 \) and \( \alpha_2 = \frac{1}{4} \hat{\tau}_2 + \frac{1}{12} \hat{\tau}_1 \). Re-scaling both divisions’ valuations in terms of \( \theta_i = \tau_i \pm I_i \) yields the linear strategies

\[
s(\theta_1, I) = \frac{1}{12} [3\hat{\theta}_2 + \hat{\theta}_1 - 9I_1 + 3I_2 + 8\theta_1] \quad \text{and} \quad \hat{\theta}_{\theta_2}(\theta_2, I) = \frac{1}{12} [\hat{\theta}_2 + 3\hat{\theta}_1 - 3I_1 + 9I_2 + 8\theta_2],
\]

given that the first-order conditions are necessary and sufficient.

The boundary conditions follow from the fact that, say, the buyer will never submit a realization in equilibrium there will be no trade, we make the assumption that division \( i \) submits its true valuation. For an extensive discussion of the boundary conditions, the reader is referred to Chatterjee and Samuelson (1983).

**Proof of Proposition 1:** According to (1), \( q^*(\theta, I_1) = 1 \) if and only if \( \theta_1 - I_1 \leq \theta_2 \). Under cost-based transfer pricing, the supplying division quotes a cost report according to (12), and trade occurs if and only if \( \theta_1 - I_1 \leq \phi(\theta_2) = \theta_2 - (1 - F_2(\theta_2))/f_2(\theta_2) \).

The first-best expected firm profit and that under standard-cost transfer pricing can be written as functions of \( \Delta_2 \equiv \hat{\theta}_1 - \hat{\theta}_2 \):

\[
\Pi^*(\Delta_2) = \int_{\hat{\theta}_1}^{\hat{\theta}_2+\Delta_2} \left[ \theta_2 - \theta_1 + I_1^*(\Delta_2) \right] dF_1(\theta_1) dF_2(\theta_2) - w_1(I_1^*(\Delta_2)),
\]

\[
\Pi'(\Delta_2) = \int_{\hat{\theta}_1}^{\hat{\theta}_2+\Delta_2} \left[ \theta_2 - \theta_1 + I_1^*(\Delta_2) \right] dF_1(\theta_1) dF_2(\theta_2) - w_1(I_1^*(\Delta_2)),
\]

where \( I_1^*(\Delta_2) \) and \( I_1'(\Delta_2) \) are determined according to (3) and (13). Now, since \( \lim_{\Delta_2 \to 0} \phi(x) = x \), it follows immediately that

\[
\lim_{\Delta_2 \to 0} \Pi'(\Delta_2) = \int_{\hat{\theta}_1}^{\hat{\theta}_2+\lim_{\Delta_2 \to 0} I_1'(\Delta_2)} \left[ \theta_2^0 - \theta_1 + \lim_{\Delta_2 \to 0} I_1'(\Delta_2) \right] dF_1(\theta_1)
\]

\[
= \lim_{\Delta_2 \to 0} \Pi^*(\Delta_2)
\]

since \( \lim_{\Delta_2 \to 0} I_1'(\Delta_2) = \lim_{\Delta_2 \to 0} I_1^*(\Delta_2) \).
Proof of Proposition 2: To show that the standard-cost-based mechanism dominates as \( \Delta_2 \to 0 \), we only need to prove that negotiated transfer pricing does not approach first-best performance. We first show that, for all \( I_1 \), \( \lim_{\Delta_2 \to 0} M^v(I_1, \Delta_2) < \lim_{\Delta_2 \to 0} M^*(I_1, \Delta_2) \), where

\[
M^v(I_1, \Delta_2) = \int_{\theta_1}^{\Delta_2} \int_{\theta_2}^{\theta_2 + \Delta_2} \left[ \theta_2 - \theta_1 + I_1 \right] q^v(\theta, I_1) \, dF_2(\theta_2) \, dF_1(\theta_1),
\]

and \( M^*(\cdot) \) is defined similarly with \( q^*(\cdot) \) substituted for \( q^v(\cdot) \). Secondly, it is demonstrated that \( \lim_{\Delta_2 \to 0} I^*_1(\Delta_2) < \lim_{\Delta_2 \to 0} I^*_1(\Delta_2) \).

As \( \Delta_2 \to 0 \), we have \( b(\theta^*_2, I_1) < \theta^*_2 \) for all \( I_1 \), by (14). Comparing (1) with (9), there is a non-empty set of \( \theta \)’s for which negotiated transfer pricing does not result in trade even though \( q^*(\theta, I_1) = 1 \). This proves the first requirement.

Similarly, by comparing (3) with (15), we find that, for all \( I_1 \), the marginal investment returns under negotiated transfer pricing are less than first-best as \( \Delta_2 \to 0 \): \( M^v_1(I_1) = \frac{3}{4} \text{Prob}[q^v(\theta, I^*_1) = 1] < \text{Prob}[q^*(\theta, I^*_1) = 1] = M^*(I_1) \).

Now suppose that, contrary to our claim, \( I^*_1 \geq I^*_1 \) would hold. By revealed preference, \( M^v_1(I^*_1) - w_1(I^*_1) \geq M^v_1(I^*_1) - w_1(I^*_1) \) and \( M^*(I^*_1) - w_1(I^*_1) \geq M^*(I^*_1) - w_1(I^*_1) \) both hold. Adding and rearranging yields

\[
\int_{I^*_1}^{I^*_1} M^*(I_1) \, dI_1 \geq \int_{I^*_1}^{I^*_1} M^v_1(I_1) \, dI_1.
\]

A necessary condition for \( I^*_1 > I^*_1 \) then is that \( M^*(I_1) \leq M^v_1(I_1) \) for some \( I_1 \), which yields a contradiction. As shown in Edlin and Shannon (1998), (A1) rules out that \( I^*_1 = I^*_1 \), which completes the proof of Proposition 2.

Proof of Proposition 3: Part i. Given Bilateral Uncertainty prevails as defined by (BU), then the expected contribution margins for given \( I_1 \) under the two schemes are:

\[
M^v_1(I_1) = \int_{\theta_1}^{\theta^*_2} \int_{\theta^*_2}^{\theta^*_2 + \Delta_2} \left[ \theta_2 - \theta_1 + I_1 \right] q^v(\theta, I_1) \, dF_2(\theta_2) \, dF_1(\theta_1),
\]

\[
M^*(I_1) = \int_{\theta_1}^{\theta^*_2} \int_{\theta^*_2}^{\theta^*_2 + \Delta_2} \left[ \theta_2 - \theta_1 + I_1 \right] q^*(\theta, I_1) \, dF_2(\theta_2) \, dF_1(\theta_1),
\]

where (22) uses the fact that \( s^{-1}(b(\theta^*_2, I_1), I_1) = b(\theta^*_2, I_1) + I_1 \). The ex-post comparison then is a matter of straightforward algebra:

\[
M^v_1(I_1) = \int_{\theta_1}^{\theta^*_2} \int_{\theta^*_2}^{\theta^*_2 + \Delta_2} \left[ \theta_2 - \theta_1 + I_1 \right] q^v(\theta, I_1) \, dF_2(\theta_2) \, dF_1(\theta_1)
\]

\[
= \frac{9}{64 \Delta_1 \Delta_2} \left( \theta^*_2 - \theta_1 + I_1 \right)^3.
\]
> \[ M^s(I_1) = \int_{\hat{\theta}_1}^{\hat{\theta}_2} \int_{\frac{1}{2}(\hat{\theta}_2 + \hat{\theta}_1 - I_1)}^{\hat{\theta}_2} [\theta_2 - \theta_1 + I_1] dF_2(\theta_2) dF_1(\theta_1) \]

\[ = \frac{1}{8\Delta_1\Delta_2} [ (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^3 - (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^3 ], \]

where the inequality holds due to \( \hat{\theta}_2 - \hat{\theta}_1 \geq 0 \), by (BU). This proves part i.

\section*{Part ii.}

It remains to be shown that \( I^s_1 > I^n_1 \). As in the proof of Proposition 2, a sufficient condition for this to hold is that the marginal investment returns are uniformly greater under cost-based pricing. The investment incentives again are determined by the supplier’s marginal contribution margin as given by (17) and (13):

\[ M^s(I_1) = \frac{3}{4} \text{Prob}[q^n(\theta, I_1) = 1] \quad \text{and} \quad M^n(I_1) = \text{Prob}[q^s(\theta, I_1) = 1]. \]

Notice that \( q^n(\theta, I_1) = 1 \) if and only if \( b(\theta_2, I_1) \geq s(\theta_1, I_1) \), while \( q^s(\theta, I_1) = 1 \) if and only if \( \theta_2 \geq t^s(\theta, I_1) \). The seller’s marginal contribution margins under the respective transfer pricing schemes can be rewritten as:

\[ M^s(I_1) = \frac{3}{4} \int_{\delta_1}^{\frac{1}{2}(\delta_2 + \delta_1 + 3I_1)} \int_{\frac{1}{2}(\delta_2 - \delta_1 - 3I_1)}^{\delta_2} dF_2(\theta_2) dF_1(\theta_1) \]

\[ = \frac{3}{4} \cdot \frac{9}{32\Delta_1\Delta_2} (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^2, \quad (24) \]

\[ M^n(I_1) = \int_{\delta_1}^{\frac{1}{2}(\delta_2 + \delta_1 - I_1)} \int_{\frac{1}{2}(\delta_2 - \delta_1 - I_1)}^{\delta_2} dF_2(\theta_2) dF_1(\theta_1) \]

\[ = \frac{1}{4\Delta_1\Delta_2} [ (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^2 - (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^2 ]. \quad (25) \]

Suppose now that, contrary to our claim, there exists some value \( I_1 \) such that \( M^s(I_1) \geq M^n(I_1) \). Then, (24) and (25) imply that

\[ (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^2 \geq \left( 1 - \frac{27}{32} \right) (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^2. \quad (26) \]

Under (BU), however, we know that \( \hat{\theta}_1 \geq \frac{1}{4} (3\hat{\theta}_2 + \hat{\theta}_1 + 3I_1) \). This yields an upper bound on the left-hand side of (26):

\[ (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^2 \leq \left( \hat{\theta}_2 - \frac{1}{4} (3\hat{\theta}_2 + \hat{\theta}_1 + 3I_1) + I_1 \right)^2 = \frac{1}{16} (\hat{\theta}_2 - \hat{\theta}_1 + I_1)^2. \]

This last expression, however, is less than the right-hand side of (26)—a contradiction. As in the proof of Proposition 2, this implies \( I^s_1 > I^n_1 \). \hfill \blacksquare
Proof of Proposition 4: Recall the first-order conditions for the seller’s investment choices under Revenue Uncertainty (RU) in the limit case where $\Delta_1 \to 0$:

$$ w'_s(I^o_s) = \frac{1}{2} \text{Prob}[q^s(\theta, I^o_s) = 1] = \frac{1}{2} [1 - F_2(s(\theta^o_s, I))] = \frac{3}{8} (1 - \theta^o_s + I_1), $$

$$ w'_s(I^o_s) = \text{Prob}[q^s(\theta, I^o_s) = 1] = 1 - F_2(t^s(\theta^o_s, I_s)) = \frac{1}{2} (1 - \theta^o_s + I_1). $$

By assumption, $w_1(I_1) = \beta_1 I_1^2$. It follows that

$$ I^o_s = \frac{1 - \theta^o_s}{2 \beta_1 - 1} > I^o_s = \frac{3(1 - \theta^o_s)}{8 \beta_1 - 3}, $$

and, for any $I_1$,

$$ M^s(I_1) = \frac{3}{8} (1 - \theta^o_s + I_1)^2 < M^s(I_1) = \frac{15}{32} (1 - \theta^o_s + I_1)^2. $$

Thus, the firm faces a tradeoff between trading and investment incentives.

The expected profits under the two schemes are

$$ \Pi'_s = M^s(I^o_s) - \frac{\beta_1}{2} I^o_s^2 = \frac{3}{8} (1 - \theta^o_s + \frac{1}{2} \theta^o_s + \frac{1}{2} \beta_1 - 1)^2 - \frac{\beta_1}{2} \left(1 - \theta^o_s + \frac{1}{2} \beta_1 - 1\right)^2 $$

$$ = \frac{\beta_1}{2} (3 \beta_1 - 1) \left(\frac{1 - \theta^o_s}{2 \beta_1 - 1}\right)^2, $$

$$ \Pi^s = M^s(I^o_s) - \frac{\beta_1}{2} I^o_s^2 = \frac{15}{32} (1 - \theta^o_s + \frac{3}{8} \beta_1 - 3)^2 - \frac{\beta_1}{2} \left(\frac{3(1 - \theta^o_s)}{8 \beta_1 - 3}\right)^2 $$

$$ = \frac{\beta_1}{2} (60 \beta_1 - 9) \left(\frac{1 - \theta^o_s}{8 \beta_1 - 3}\right)^2. $$

Now, a necessary condition for the investment effect to dominate is that

$$ \Pi'_s - \Pi^s = \frac{\beta_1}{2} (1 - \theta^o_s)^2 \left[\frac{3 \beta_1 - 1}{(2 \beta_1 - 1)^2} - \frac{60 \beta_1 - 9}{(8 \beta_1 - 3)^2}\right] > 0 \Rightarrow \beta_1 < 1. $$

We now show that $\beta_1 < 1$ is inconsistent with interior first-best investments, as stipulated by (A1). The first-best investments solve

$$ w'_s(I^*_s) = \beta_1 I^*_s = \text{Prob}[q^*(\theta, I^*_s) = 1] = 1 - \theta^o_s + I_1 \Rightarrow I^*_s = \frac{1 - \theta^o_s}{\beta_1 - 1}. $$

By condition (RU), we have $I^*_s < \theta^o_s$. Requiring $I^*_s < \theta^o_s$ yields a contradiction since

$$ I^*_s = \frac{1 - \theta^o_s}{\beta_1 - 1} < \frac{1}{\theta^o_s} \Rightarrow \beta_1 > \frac{1}{\theta^o_s} > 1. $$
Proof of Proposition 5: Proceeding in a similar fashion as in the proof of Proposition 3, first note that the marginal investment returns for the buying division under the two regimes are given by

\[
M^n_2(I_2) = \frac{3}{4} \text{Prob}[q^n(\theta, I_2) = 1] \quad \text{and} \quad M^s_2(I_2) = \frac{1}{2} \text{Prob}[q^s(\theta, I_2) = 1].
\]

The ex-post probabilities of trade under Bilateral Uncertainty, (BU), are given by

\[
\text{Prob}[q^n(\theta, I_2) = 1] = \frac{9}{32\Delta_1\Delta_2} (\tilde{\theta}_2 - \tilde{\theta}_1 + I_2)^2,
\]

\[
\text{Prob}[q^s(\theta, I_2) = 1] = \frac{1}{4\Delta_1\Delta_2} [(\tilde{\theta}_2 - \tilde{\theta}_1 + I_2)^2 - (\tilde{\theta}_2 - \tilde{\theta}_1 + I_2)^2].
\]

Since \(\tilde{\theta}_2 - \tilde{\theta}_1 \geq 0\), we have \(\text{Prob}[q^n(\theta, I_2) = 1] > \text{Prob}[q^s(\theta, I_2) = 1]\) and, a fortiori, \(M^n_2(I_2) > M^s_2(I_2)\), for all \(I_2\). This in turn implies \(I^2_n > I^2_s\). At the same time, modifying Proposition 3 for the case of buyer investments yields \(M^n_2(I_2) > M^s_2(I_2)\), for all \(I_2\).

To complete the proof, we use ex-post dominance of negotiations for the first of the following inequalities:

\[
\Pi^s(I^2_2) = M^s_1(I^2_2) + M^s_2(I^2_2) - w_2(I^2_2)
\]

\[
< \Pi^n(I^2_2) = M^n_1(I^2_2) + M^n_2(I^2_2) - w_2(I^2_2)
\]

\[
\leq \Pi^n(I^s_2) = M^n_1(I^s_2) + M^n_2(I^s_2) - w_2(I^s_2).
\]

The last inequality holds, since, by (A2), \(\Pi^n(I^s_2)\) is single-peaked, and

\[
\hat{I}^n_2 = \arg\max_{I_2} \{M^n_2(I_2) + M^n_2(I_2) - w_2(I_2)\}
\]

\[
> I^n_2 = \arg\max_{I_2} \{M^n_2(I_2) - w_2(I_2)\}
\]

\[
\geq I^s_2,
\]

by revealed preference. Hence, \(I^2_n\) and \(I^2_s\) both fall within the region where \(\Pi^n(I^2_2)\) is monotone non-decreasing (by (A2)) which completes the proof of Proposition 5.

Proof of Proposition 6: Rewriting the objective function and replacing (IC) in Program I with its first-order condition—which is feasible by (A3)—we get the following equivalent representation of Program 1:

\[
t^* \in \arg\max_t \left\{ \frac{1}{2\Delta_1\Delta_2}(\bar{\theta}_2 - t)(t - \bar{\theta}_1 + I_1)(\bar{\theta}_2 - \bar{\theta}_1 + I_1) - w(I_1) \right\}.
\]

subject to:

\[
I_1 \in \arg\max_{I_1} \left\{ \frac{1}{\Delta_1\Delta_2} (\bar{\theta}_2 - t)(t - \bar{\theta}_1 + \bar{I}_1) - w'(I_1) \right\}.
\]

(27)
From (27) and (IC), it is obvious that, holding investments fixed, the same value $t$ that maximizes the objective function, also maximizes investments (which are driven by the probability of trade). Notice further that the seller’s objective in (IC) is concave in $I_1$ by (A3) and that the firm’s objective in (27) is increasing in $I_1$ for all values of $I_1$ for which the selling division’s profit, as given in (IC), is increasing in $I_1$. Thus, solving Program I is equivalent to solving

**Program I’:**

$$t^c = \frac{1}{2}(\bar{\theta}_2 + \bar{\theta}_1 - I_1(t^c)),$$

where $I_1(t)$ solves (IC) for any $t$. Let $I_1^c$, $M^c$ and $\Pi^c$, respectively, denote the resulting seller investment, expected firm-wide contribution margin and expected firm-wide profit under Program I’.

The proof proceeds along two steps: we first show that $I_1^c \leq I_1^c$, and then prove ex-post (trade) dominance of centralized transfer pricing. Under standard-cost transfer pricing, the seller’s marginal investment return for any $I_1$ is (see (25)):

$$M_1^c(I_1) = \frac{1}{4\Delta_1\Delta_2}[(\bar{\theta}_2 - \bar{\theta}_1 + I_1)^2 - (\bar{\theta}_2 - \bar{\theta}_1 + I_1')^2].$$

Under centralized transfer pricing (Program I’), given that $t = t^c = \frac{1}{2}(\bar{\theta}_2 + \bar{\theta}_1 - I_1^c)$, the supplier’s marginal investment return for any $I_1$ is found by differentiating

$$M_1^c(I_1, t^c) = \int_{\bar{\theta}_1}^{t^c + I_1} \int_{\bar{\theta}_2}^{\bar{\theta}_2} [t^c - \bar{\theta}_1 + I_1] dF_2(\bar{\theta}_2) dF_1(\bar{\theta}_1) - w_1(I_1)$$

with respect to $I_1$:

$$\frac{\partial M_1^c(I_1, t^c)}{\partial I_1} = \frac{1}{4\Delta_1\Delta_2}[(\bar{\theta}_2 - \bar{\theta}_1 + I_1)^2 - (I_1 - I_1^c)^2].$$

Now, in equilibrium, $I_1 = I_1^c$, and the necessary first-order condition reads

$$w_1'(I_1^c) = \frac{\partial M_1^c(I_1^c, t^c)}{\partial I_1} \bigg|_{I_1^c} = \frac{1}{4\Delta_1\Delta_2}(\bar{\theta}_2 - \bar{\theta}_1 + I_1^c)^2.$$

Assumption (A3) ensures that all investment problems are strictly concave in $I_1$. Now suppose that, contrary to our claim, $I_1^c > I_1^c$ would hold. A necessary condition for this to be the case is that

$$M_1^c(I_1^c) = \frac{1}{4\Delta_1\Delta_2}[(\bar{\theta}_2 - \bar{\theta}_1 + I_1^c)^2 - (\bar{\theta}_2 - \bar{\theta}_1 + I_1^c)^2] > \frac{\partial M_1^c(I_1^c, t^c)}{\partial I_1} \bigg|_{I_1^c},$$

which obviously yields a contradiction because $\bar{\theta}_2 - \bar{\theta}_1 \geq 0$, by (BU). Also note that $I_1^c < I_1^{c*}$, where $I_1^{c*} = \arg \max_{I_1} \{M_1^c(I_1) + M_2^c(I_1) - w_1(I_1)\}$. This holds because

$$\frac{d(M_1^c(I_1) + M_2^c(I_1))}{dI_1} \bigg|_{I_1^c} = \frac{3}{8\Delta_1\Delta_2}[(\bar{\theta}_2 - \bar{\theta}_1 + I_1^c)^2 - (\bar{\theta}_2 - \bar{\theta}_1 + I_1^c)^2] > \frac{1}{4\Delta_1\Delta_2} (\bar{\theta}_2 - \bar{\theta}_1 + I_1^c)^2 = \frac{\partial M_1^c(I_1, t^c)}{\partial I_1} \bigg|_{I_1^c},$$

where $\bar{\theta}_2$ and $\bar{\theta}_1$ are the expected investment returns for the seller and the firm, respectively.
where the inequality is derived in a similar fashion as in the proof of Proposition 3, i.e., by invoking the lower bound on $\theta_{t}$ as stated in (BU). Hence, $I_{c}^{1} \leq I_{c}^{\ast} < I_{s}^{\ast}$. Thus, by (A3), we have $\Pi'(I_{c}^{1}) > \Pi'(I_{c}^{\ast})$, which yields the first of the following inequalities:

$$\Pi' = M'(I_{c}^{1}) - w_{1}(I_{c}^{1})$$

$$\leq M'(I_{c}^{\ast}) - w_{1}(I_{c}^{\ast})$$

$$< M'(I_{c}^{\ast}, t^{c}) - w_{1}(I_{c}^{\ast}) \equiv \Pi^{'\ast}.$$  

The strict inequality follows from the fact that the expected contribution margin, evaluated at $I_{c}^{1}$ and $t^{c}$, is strictly greater under the centralized scheme:

$$M'(I_{c}^{1}, t^{c}) = \int_{\theta_{c}}^{\theta_{c}^{b}} \int_{\theta_{c}}^{\theta_{c}^{b}} [\theta_{2} - \theta_{1} + I_{1}^{1}] dF_{2}(\theta_{2}) dF_{1}(\theta_{1}) = \frac{1}{8\Delta_{1}\Delta_{2}} \left( \theta_{2} - \theta_{1} + I_{1}^{1} \right)^{3}$$

$$> M'(I_{c}^{\ast}) = \frac{1}{8\Delta_{1}\Delta_{2}} \left[ \left( \theta_{2} - \theta_{1} + I_{c}^{\ast} \right) - \left( \theta_{2} - \theta_{1} + I_{c}^{1} \right) \right]^{3}.$$

**Proof of Proposition 7:** Part i. By slightly abusing notation, we first note that, holding $I_{c}$ fixed, $t'^{c}(I_{c}) = \frac{1}{2}(\theta_{c} + \theta_{s} - I_{c})$ maximizes $M'(I_{c}, t)$ over all $t$. Hence, we only need to show that $M^{n}(I_{c}) > M^{n}(I_{c}, t^{c}(I_{c}))$, for all $I_{c}$. This is indeed the case as

$$M^{n}(I_{c}) = \frac{9}{64\Delta_{1}\Delta_{2}} \left( \theta_{2} - \theta_{1} + I_{c} \right)^{3} > M^{n}(I_{c}, t^{c}(I_{c})) = \frac{1}{8\Delta_{1}\Delta_{2}} \left( \theta_{2} - \theta_{1} + I_{c} \right)^{3}.$$

**Part ii.** Assumption (A3) ensures that all investment problems are strictly concave. Thus, we only need to show that the buyer’s marginal investment return, evaluated at $I_{c}^{1}$ (and at $t^{c}$), is greater under centralized transfer pricing than under negotiations:

$$\frac{\partial M'(I_{c}, t^{c})}{\partial I_{c}} \bigg|_{I_{c}^{1}} = \frac{1}{4\Delta_{1}\Delta_{2}} \left( \theta_{2} - \theta_{1} + I_{c}^{1} \right)^{2} > M'^{c}(I_{c}^{1}) = \frac{3}{4} \frac{9}{32\Delta_{1}\Delta_{2}} \left( \theta_{2} - \theta_{1} + I_{c}^{1} \right)^{2}.$$

This completes the proof of Proposition 7.

**Notes**

1. We implicitly assume that there is no viable external market for the intermediate product. Among cost-based mechanisms, many firms prefer standard cost over actual cost in a multi-product setting, as actual costs for a particular product are often difficult to verify. Furthermore, under a standard-cost system, the selling division has an incentive to keep actual production cost low, while the buying division knows at the outset the amount it will have to pay. See Price Waterhouse (1984), Eccles (1985), Tang (1992) or Horngren, Foster and Datar (1997).

2. Recent contributions to the literature on incomplete contracting have demonstrated that the hold-up problem can be overcome if the divisions enter into a contractual agreement at the outset; see, e.g., Chung (1991) or Edlin and Reichenstein (1995). We will assume, however, that the intermediate good cannot be contractually specified at an early stage. Similar assumptions are employed by Williamson (1985), Grossman and Hart (1986), and Holmström and Tirole (1991). According to the Price Waterhouse (1984) survey, formal contracts between divisions are rarely observed.


5. Kanodia (1991) elaborates on the role of rent extraction in transfer pricing models. We assume that the managers’ bonuses are functions of divisional income only. As in most incomplete contracting models without moral hazard, underinvestment problems could be mitigated by basing the managers’ salaries on firm-wide profit, \( \Pi = \sum_i [M_i - w_i(L_i)] \), see Heavner (1998). However, in most cases internal transactions constitute only “additional business” for the divisions (Tang (1993)). Moral hazard problems associated with other projects keep profit sharing from attaining first-best; see Anctil and Dutta (1999). Eccles (1985), Merchant (1988) and Bushman, Indjejikian and Smith (1995) observe that divisional performance measures generally are the main drivers of division managers’ compensation.

6. Note that all results below remain valid in the case where the seller quotes \( t^s \) before knowing his actual cost. Suppose that actual costs are given by \( \theta_1 - I_1 + \varepsilon \) where \( \varepsilon \) is a random variable with zero mean. The seller submits a cost report \( t^s \) after privately observing \( \theta_1 \) but before observing \( \varepsilon \), i.e. the seller is better informed than the central office but he is not perfectly informed. This seems to correspond closely to the definition of standard costing found in textbooks.

7. The corner solutions corresponding to (4) are: \( t^s(\cdot) = \bar{\theta}_2 + I_2 \) if \( \theta_1 - I_1 < \phi(\bar{\theta}_2, I_2) \), and \( t^s(\cdot) = \theta_1 - I_1 \) if \( \theta_1 - I_1 > \bar{\theta}_2 + I_2 \). We invoke the standard assumption that the inverse hazard rate \( (1 - F_2(\cdot)) / f_2(\cdot) \) be monotonic.


9. Linhart, Radner and Satterthwaite (1992) point out that sealed-bid mechanisms suffer from commitment problems in voluntary trading situations. While sequential bargaining may be more descriptive for intrafirm negotiations, such models are very sensitive with respect to belief revisions under two-sided private information. Notice that a sealed-bid mechanism minimizes “haggling costs.”

10. Leininger, Linhart and Radner (1989) show that the symmetrical sealed-bid mechanism has infinitely many equilibria, including non-differentiable ones. However, they provide references to experimental studies suggesting that players’ actual bidding strategies often are approximately linear. The result stated in Lemma 1 reflects the only polynomial equilibrium strategies.

11. It is straightforward to construct a generalized bargaining mechanism where both divisions submit bids and \( t(s, b) = as + (1 - a)b \). Then \( a = 1/2 \) (\( a = 1 \)) corresponds to negotiated (standard-cost) transfer pricing. As the flip-side of standard-cost transfer pricing, \( a = 0 \) would characterize a mechanism where the payment is based solely on a net-revenue report issued by the buyer. In Balduccini, Reichelstein and Sahay (1999), in contrast, standard-cost transfer pricing is not a limit case of negotiations because the seller, while indeed entitled to make a take-it-or-leave-it offer, is restricted to uniform pricing and quantity is a continuous variable.

12. All first-order investment conditions and bidding strategies are summarized in Appendix A.

13. This finding is in line with Vaýsman’s (1998) result that the performance of negotiated transfer pricing improves if bargaining power is allocated to the privately informed division.

14. As a technical condition, we require the buyer’s highest valuation to be greater than the seller’s highest cost for all investments, and similarly for the lowest valuations. Moreover, (BU) ensures that only the lower two branches of (10) and (11), respectively, arise with positive probability. In order to ensure that \( [\bar{\theta}_1 - I_1, \bar{\theta}_1 - I_1] \) and \( [\bar{\theta}_2 + I_2, \bar{\theta}_2 + I_2] \) intersect for all \( (I_1, I_2) \), the sum \( \bar{I}_1 + \bar{I}_2 \) must not be too large.

15. In contrast to previous transfer pricing models concerned with hold-up problems under symmetric information—e.g., Holmström and Tirole (1991), Edlin and Reichelstein (1995)—we can explicitly track how the bargaining strategies of the divisions change if one of them makes specific investments.

16. As noted earlier, the equilibrium derived in Lemma 1 is not unique. If now \( \Delta_2 \to 0 \), then the problem of multiple equilibria may be perceived as more severe. However, dominance of standard-cost transfer pricing...
may still be defended on the grounds of its unique efficient subgame-perfect equilibrium, whereas under negotiated transfer pricing there is an infinite number of inefficient equilibria in addition to the efficient one. As long as the buyer’s bargaining power allows him to achieve a strictly positive contribution margin, Proposition 2 will continue to hold.

17. Notice that, in equilibrium, $s^{-1}(h(\hat{\theta}, I_1)) = h(\hat{\theta}, I_1) + I_1$.


19. In contrast to the present paper, Mookherjee and Reichelstein (1992) model negotiated transfer pricing as an optimal Myerson–Satterthwaite mechanism. However, if there is one-sided private information, such a mechanism can be shown to achieve first-best performance. Thus, the optimal mechanism coincides with a regime that grants unfettered bargaining power to the privately informed manager, with distributive issues being dealt with by up-front payments from the informed to the uninformed division. While this is of eminent normative importance, it does not seem descriptive for intrafirm trade. Under a sealed-bid mechanism, in contrast, both divisions benefit from incremental contribution margins, even if the valuation of one division is observable.

20. For this case of quadratic investment costs, numerical simulations suggest that the trade effect tends to dominate under Bilateral Uncertainty, as well.

21. A sufficient condition for this to hold is that $w^2(\hat{\theta}) > \frac{\alpha}{\beta}(\hat{\theta} + I_2 - \hat{\theta})/(\Delta_1 \Delta_2)$, for all $I_2$. Notice that concavity of $\Pi^*(I_2) = M^*(I_2) - w^*(I_2)$ does not imply (A2).

22. For specific scenarios we can conduct profit comparisons. Suppose that one-sided revenue uncertainty prevails, both divisions’ investment costs are described by symmetric functions $w_1(I_1) = \beta/I_1^2$, and first-best expected profits $\Pi^*(I_1, I_2)$ are concave in each argument with $(I_1^*, I_2^*) \in (0, I_1) \times (0, I_2)$. Then negotiated transfer pricing dominates standard-cost transfer pricing.

23. I am grateful to Rick Lambert and a referee for suggesting this scenario. A more general model is conceivable, where the center observes noisy signals $[\theta_i + \epsilon_i, \bar{\theta}_i + \bar{\epsilon}_i]$ about the divisional parameter supports $\theta_i$. If the variance of the random terms, $\epsilon_i$, is sufficiently large, then, endogenously, the center would not want to exercise its option to determine $r$ in a centralized fashion.

24. Textbooks argue that the seller has to be granted a fair share of the total profit at the expense of reduced contribution margins. The symmetric information models of Sahay (1997) and Baldenius, Reichelstein and Sahay (1999), the optimal mark-up over actual cost trades off investment incentives for the seller versus trade distortions. If the seller has no investment opportunity, the optimal mark-up in these models will be zero.

25. A related idea is applied in Arya, Glover and Sivaramakrishnan (1997).

References


