Negotiated versus cost-based transfer pricing for storable products

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Abstract

This paper studies a repeated incomplete contracting model to compare the effectiveness of two alternative transfer pricing schemes. Previous analytical work has suggested a dominance of negotiated over cost-based transfer pricing based on a one-shot model. However, this result lacks empirical support as cost-based methods are widely used in practice. In this article we revise the dominance result for storable products. In contrast to the one-shot model, production lots may be aggregated in the multi-period setting. This allows the exploitation of scale effects but requires inventory to be built. The capital tied in inventory creates a new hold-up problem to which negotiation is prone. We suggest that negotiated transfer pricing may induce suboptimal lot scheduling characterized by small batch production to avoid storage. In particular, we find that cost-based transfer pricing may outperform negotiation when investments contribute significantly to overall profits and if retail margins are thin.

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1. Introduction

Empirical findings suggest that multiple transfer pricing mechanisms prevail in practice, which can coarsely be categorized as market-based, cost-based or negotiated[2]. In cases where an external market for the traded good does not exist, the latter two pricing schemes are of particular importance. In this paper a performance evaluation of these two transfer pricing methods is conducted in a dynamic setting.

To create effort incentives and mitigate agency problems divisional managers are usually compensated based on the profit of the division they operate. The purpose of aligning the division managers' incentives with the higher interest of the firm is then assigned to transfer pricing. However, the decisions that need to be coordinated may be diverse and tradeoffs exist. To illustrate this, previous research has specified two objectives of transfer pricing, the guidance of the trading volume as well as the creation of incentives for relationship-specific investments[3]. Such investments may include personnel training or machinery and equipment. In general such analyses have considered a single trade event where investments entail an upfront fixed cost and a subsequent reduction in the unit variable cost incurred by the supplying division.

We argue, however, that a one-shot model does not well represent the sustainable nature of intracompany trade relations. Further, single-period analyses are not rich enough to account for production lot scheduling and inventory decisions, which may significantly impact the firm's performance[4]. This paper extends the analysis of Baldenius et al. (1999) by a repeated period of investment and trade, where inventories can leverage the utilization of investment costs. It is understood that returns from investments deteriorate over time. Thus, reinvestments are required to keep personnel trained and equipment available. For simplicity it is assumed here that an investment only reduces the cost of goods produced in the same period. Produces are either sold immediately or stored for future liquidation. To reduce production costs in the next period, a new investment is required.

It is well known that inventories are frequently part of efficient operations. For example, cycle inventory is carried to exploit economies of scale. Where production requires a large amount of fixed costs, it may be beneficial to aggregate demands of multiple periods into one large production lot to avoid recurrent fixed costs. However, while inventories may

[2] See, for example, Price Waterhouse (1984) or Eccles (1985).
[3] See, for example Edlin and Reichelstein (1995), Baldenius et al. (1999), or Pfeiffer et al. (2011).
[4] Inventory decisions have been central to multi-period agency settings such as Dutta and Zhang (2002) and Baldenius and Reichelstein (2005). However, these models do not assign the production and retailing tasks to two different divisions and do not focus on transfer pricing issues.

create value, they tie capital. When the inventory decision is made at the divisional level, stimulating incentives for stockkeeping must clearly be a third objective of transfer pricing. To capture the tradeoff between periodic production and satisfaction of orders from stock, the producing division has control over inventory in this model[5].

Earlier literature suggests that negotiated transfer pricing chronically suffers from underinvestment (e.g., Williamson 1985, Grossman and Hart 1986, and Holmström and Tirole 1991). When each division is able to claim some share of the total gains from trade in negotiations, neither party can incorporate the full return of the investment. If divisions bear the full cost of the investment, however, a "hold-up" problem arises causing suboptimal investment decisions.

In the multi-period model, the capital tied in inventories creates another "hold-up" problem. The producer makes an investment in inventory, which is relationship-specific in the absence of an alternative user of the intermediate product. In particular, costs for producing the stocks are "sunk" in the period of liquidation. Facing negotiations, the producer can only expect to claim a fraction of the joint gains from selling the inventory. Thus, the net profit the producer expects from carrying stock may not exceed that of a repeated production run. Contractual agreements can mitigate the lack in investment incentives (e.g., Edlin and Reichelstein 1995). This also applies for incentives for carrying inventory. However, this possibility is ignored, as formal contracts appear not to be common in intrafirm relations (e.g. Price Waterhouse 1984, and Eccles 1985).

In this model of cost-based transfer pricing, a reported standard cost is used following Baldenius et al. (1999). The producing division (seller) issues a cost report and the retailing division (buyer) decides how many units of the good it wants to purchase at this cost. The reported cost serves as the transfer price in the absence of verifiability of the true cost value to a central office. The transfer price is revalued in each trading period[6]. Allowing the seller to name an arbitrary price effectively assigns monopoly power to him. This intentionally pushes the argument to the limit that the producing division tends to exaggerate costs under standard-cost transfer pricing (e.g., Eccles and White 1988). The inclusion of a profit margin into the reported cost gives rise to the well known double marginalization effect resulting in a suboptimal trading volume (e.g., Spengler 1950).

[5] For purposes other than the ones modeled here, demand uncertainty for example, it is certainly viable for the buying or both stages to hold inventory.

[6] According to Eccles (1985, p.44) transfer prices are usually changed annually, quarterly or as needed. A main determinant for the timing of price adjustments is the revaluation of standard cost.

By entailing a reduction of the unit production cost, the value of the investment clearly depends on the production output. In the single-period analysis of Baldenius et al. (1999) production and transfer volumes coincide, which links the two objectives of transfer pricing. The low transfer volume under cost-based pricing curtails investment incentives, which primarily leads the authors to conclude that this mechanism is generally inferior to negotiated transfer pricing. However, in a dynamic setting, production and trade volumes may not coincide on a periodical basis. Produces made to stock may bolster the production lot size, which ultimately determines the investment incentive.

Just as cost-based transfer pricing avoids the hold-up problem concerning the cost-reducing investment it also avoids the hold-up problem regarding the capital tied in inventories. Thus, under cost-based transfer pricing, the seller may create inventories and reduce production costs more aggressively than he would under negotiations. The higher investment causes the seller to quote a lower standard cost, which mitigates the transfer quantity distortion. This illustrates how the three transfer pricing tasks interrelate in the multi-period setting. Incentives for stockkeeping create incentives for cost-reducing investments, which in turn stimulate the trade volume.

It continues to hold that the trade volume is higher under negotiations. However, we observe a higher willingness to invest under cost-based transfer pricing. Altogether, the dominance relationship found in Baldenius et al. (1999) cannot be reinforced if the hold-up problem extends to inventories. It is shown here that cost-based transfer pricing is indeed able to outperform negotiations. In general, the firm picks cost-based over negotiated transfer pricing when cost-reducing investments are effective, i.e. when efficient production includes a sizable upfront fixed cost. However, cost-based is only the pricing mechanism of choice, if the (expected) unit production cost is relatively high, i.e. if the retail margin is thin. This moderates the efficiency loss due to distorted transfer volumes. Contrary, the firm is better off under negotiations when investments are little effective and when retail margins are high.

Like Baldenius et al. (1999) this model follows the approach to compare two transfer pricing models prevalent in practice. It does not intend to find an optimal transfer pricing mechanism. Likewise, it is assumed that divisions have imperfect but symmetric information about the relevant state variables. The model abstains from moral hazard or managerial compensation issues. Managers simply maximize the expected divisional profit. The rest of the paper is organized as follows. The basic model and the first-best solution are presented in Section 2. In Section 3 we compare the performances of a cost-based and a negotiated transfer pricing scheme. Concluding remarks are presented in Section 4.

2.1. The Model

Consider a multidivisional firm consisting of two divisions and a headquarter (HQ). The two divisions operate in separate markets except for an intermediate good that can be transferred inside the firm. The upstream division, which is referred to as seller or *S*, produces the good, which is supplied to the downstream division, referred to as buyer or *B*. The buyer processes the good and sells it to the outside customer.

The planning horizon expands over two selling cycles, after which the firm is sold and the division managers are released. In each cycle, the supplying division may lower the variable cost of production by undertaking an upfront specific investment, I_t, for example by training staff or installing equipment. The cost reducing effect of investment is short-lived, i.e. the investment only reduces the production cost in the current but not in the subsequent cycle[7]. To leverage the investment, the seller can produce inventory during the first season, which is liquidated in the second. The initial investment decision is made when the production cost is still uncertain. Uncertainty is captured by the random variable θ. The current analysis focuses on the incentives created by transfer pricing rules on economic lot sizing. To ensure that incentives for holding *cycle* inventory does not interfere with those held for *speculative* purposes, second period production costs are deterministic at the time the inventory decision is made, i.e. the seller knows the opportunity costs of inventory. In particular, we assume that, once realized, production cost (prior to investment) is constant over time. Implicitly, while the second period investment occurs too late into the product life cycle to be leveraged, it has the advantage of being made under production cost certainty. Figure 1 depicts the sequence of events.

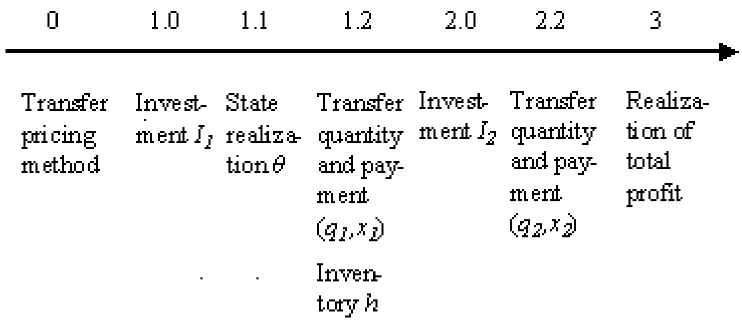

Figure 1: Timeline

[7] In this model, inventory serves the purpose to preserve the cost reducing effect of investment, which would else cease to exist. Consequently, the efficiency gains from holding inventory decrease if the investment benefit deteriorates less quickly. In the extreme case where the cost reducing effect does not fade at all, there is absolutely no benefit of carrying inventory and the Baldenius et al. (1999) solution will apply.

At date 0, the central office installs a particular transfer pricing method, which will be employed throughout the game. That is, in each period the divisions either determine the transfer quantity and payment in free negotiations or the buyer places an order at the unit cost reported by the seller. Due to changes in the effective (post-investment) production cost, the transfer price is revalued in each trading period. The mechanism in place, however, is considered a strategic decision which cannot be switched *ad hoc* in the course of the game. At date 0, the division managers and the central office have homogenous expectations with respect to the cost and revenue functions as well as θ.

At date 1.0, and 2.0 respectively, the supplier chooses a specific investment I_t, which will reduce the production cost in the respective cycle. These investments create a divisional fixed cost. For simplicity let these costs be constant over time represented by the function $w(I_t)=½\alpha(I_t)^2$, with t=1,2 for the respective selling cycle[8]. The parameter α determines the cost function, with investments being cheaper for low values of α and more expensive for higher values.

At date 1.1, the random variable θ realizes determining the production cost, which prevails throughout the game prior to investments. This translates to the setting, where a second, perfectly correlated, random variable realizes at some date 2.1. Investments and the realization of θ are perfectly observed by both divisional managers[9]. The divisions have perfect and symmetric knowledge of the cost and revenue structure in the prevailing period. However, according to the theory of specific investments, the central office does not observe or learn this information.

At date 1.2, and 2.2 respectively, the transfer pricing mechanism determines the actual transfer quantity q_t and transfer payment x_t from the buyer to the seller in the respective period. Contingent transfer rules are infeasible, as neither the investments, I_t, nor the realization of θ are considered verifiable to a third party including the central office.

Also at date 1.2, the seller chooses an inventory level h, which is observable to the buyer. These goods are produced at the effective production cost prevalent in the first period and are available for trade in the second period. There are no capacity constraints for production or holding. In absence of formal intra-company agreements, the divisions do not contract on h at any time. The seller ties his own capital in inventory. Clearly, cyclic

[8] That quadratic cost function has been proposed in Baldenius and Reichelstein (1998), which analyzes a more restricted version of Baldenius et al. (1999).
[9] This is a standard assumption in the incomplete contracting literature. An exception is Pfeiffer et al. (2011) who analyze a single-period model of cost-based transfer pricing, where one division observes the state imperfectly.

inventory is economically feasible only when holding costs are sufficiently small. To intentionally exaggerate its operational benefit, holding costs are assumed to be negligible.

Date 3 represents the end of the game, where firm as well as divisional profits realize. The model neglects any time value of money. Therefore, external and internal sales as well as profits are equally valued, whether they realize in the first or the second cycle. It is further assumed that divisions are run as independent profit centers and that a divisional manager's compensation is closely tied to divisional profits. Thus, divisional managers are expected to maximize their individual division's expected income over the entire game. Risk neutrality is further assumed[10]. Note the sequence of events matches Baldenius et al. (1999) in absence of the second cycle (dates 2.0 to 2.1).

The firm's total profits, Π, are the revenues accumulated during two selling cycles net all production and investment costs. In each cycle, revenues amount to: $R_t(q_t)\equiv[1\text{-}½q_t]q_t$ for t=1,2. Without loss of generality we restrict our analysis to this special case of the linear demand function $R_t(q_t)\equiv[a\text{-}½bq_t]q_t$. Revenues accrue at the buying division, whose processing costs for the good are normalized to zero. Cash expenses are incurred at the selling division, which bears the production as well as the investment costs. Production costs, C_t, depend on the state, θ, the current investment, I_t, and the production quantity, r_t. These amount to:

$$C_t(r_t,I_t,\theta) \equiv (c(\theta)\text{-}I_t)r_t.$$ [11]

The production quantity is decomposed into direct sales, q_t, and inventory, h, such that r_1=(q_1+h) and r_2=(q_2-h) applies. We can define the firm's cash flows in each cycle as $CF_t \equiv R_t$ -C_t-$w(I_t)$, with $\Pi = CF_1 + CF_2$. The revenue (cost) function is monotonic and strictly increasing (linear) in q and investments I_t induce a parallel translation of the cost function.

For notational convenience, we introduce $d(\theta)\equiv1\text{-}c(\theta)$, which represents the (unit) contribution margin before investments. The lowest (highest) cost realization returns the highest (lowest) contribution margin. Particularly, the margin is zero if a cost of one realizes. We assume that the unit cost $c(\theta)$ follows a uniform distribution over the interval [c_l, 1], which implies $d(\theta)$~U[0, d_h], where c_l is the lowest cost and d_h is the highest retail margin that can possibly realize.

[10] This is also a standard assumption. An exception is Anctil and Dutta (1999) who analyze a model where risk-averse managers are compensated based on divisional and/or firm performances.

[11] To prevent inference of investments from the cost realization, uncorrelated noise terms, ε_t , can be added with E[ε_t]=0 (cf. Baldenius et al., 1999). When managers are risk-neutral and ε realizes after all decisions in a period are made, these will not alter decisions. For simplicity these noise terms are omitted here.

2.2 First-Best Situation:

In the first-best situation we abstract from conflicting interests, i.e. the divisions make their decisions in the best interest of the firm. The firm's expected total profit, *Π*, is maximized in this situation.

$$\max_{q_2(I_2,h,\theta),I_2(h,\theta),h(I_1,\theta),q_1(I_1,\theta),I_1}\left\{\Pi \equiv E_\theta\left[\sum_{t=1,2} CF_t\right]\right\}.$$

The solution to the problem is found using the principle of backward induction. At date 2.2, the divisions set the trading quantity of the second cycle. At this time all other variables are known. Therefore, the divisions will trade and sell the *ex post efficient* quantity.

$$q_2^{ex}(I_2,h,\theta)\in\arg\max_{q_2}\{\Pi\}=\left\{\begin{matrix} d(\theta)+I_2 & for & 0\le h<d(\theta)+I_2 \\ h & for & d(\theta)+I_2\le h<1 \\ 1 & for & 1\le h \end{matrix}\right\}.$$

The upper term inside the parenthesis represents the optimal transfer quantity at the prevailing cost of production. For sufficiently large inventory levels, second period sales are served entirely from stock (middle term). In this case, no production will occur in the second period. The lower term prevents sales at a negative marginal return. Directly from q_2^{ex} follows the optimal production volume, r_2^{ex}:

$$r_2^{ex}(I_2,h,\theta)=\left\{\begin{matrix} d(\theta)+I_2-h & for & 0\le h<d(\theta)+I_2 \\ 0 & for & d(\theta)+I_2\le h \end{matrix}\right\}.$$

At date 2.0, the seller chooses I_2 to reduce the production cost of the second cycle:

$$\Pi^c=\Pi_S^c+\Pi_B^c=\frac{1}{d_h}\left[\int_0^{d_h} ¾(x+I_1)^2\,dx\right]-½\alpha(I_1)^2 \quad for \quad I_1\ge d_h H. \qquad (1)$$

The returns to this investment depend on the size of the production lot, which is lower when stocks are on hand. If inventories exceed a threshold, then no investment is made. Applying forward induction we find that production is positive if and only if investment is positive. In particular we obtain:

$$q_2^{fb}(h,\theta)=\begin{cases}\dfrac{\alpha\cdot d(\theta)-h}{\alpha-1} & for \quad 0\le h<d(\theta)\\ h & for \quad d(\theta)\le h\end{cases}.$$

Substituting the *ex post* efficient decisions of the second cycle in the respective cash-flow function we further receive

$$CF_2^{fb}(h,\theta)=\begin{cases}\dfrac{h^2+h(2\alpha\cdot c(\theta)-2)+\alpha(d(\theta))^2}{2(\alpha-1)} & for \quad 0\le h<d(\theta)\\ h-½h^2 & for \quad d(\theta)\le h<1\\ ½ & for \quad 1\le h\end{cases}.$$

This is then substituted into the expected total profit function. Note that $CF_2^{fb}(h,\theta)$ is continuous at $h=d(\theta)$.

At date 1.2, the seller determines the inventory amount. In optimum, h is chosen such that the marginal production cost of inventory, $c(\theta)$-I_1, is offset by the marginal second period cash flow. The inventory level will therefore depend on the investment chosen in the first cycle. Note that the expected profit is convex in h for $h<d(\theta)$, but concave and increasing for $h\geq d(\theta)$. Thus, the optimal inventory decision is either zero or a unique positive amount which is sufficiently large to render a second production run redundant[12]. In particular, expected profits are maximized at:

$$h^{fb}(I_1,\theta)\in \arg\max_h\{\Pi\}=\begin{cases}0 & for \quad \dfrac{\alpha(d(\theta))^2}{2(\alpha-1)}>\dfrac{(d(\theta)+I_1)^2}{2}\\ d(\theta)+I_1 & else\end{cases}. \tag{2}$$

No inventory is built, if the cash flow from setting up a second production run net costs of a new investment (left hand side) is greater than the contribution margin evaluated at first period production costs (right hand side). If the opposite holds, the amount stocked is $d(\theta)+I_1$,

[12] This finding is consistent with the *zero-inventory property* in operations management, which suggests that, under deterministic demand, either zero inventory should be held or sufficient to satisfy an entire period's demand (cf. Wagner and Whitin, 1958).

which is sufficient to waive produce in the second period. The condition illustrates the trade-off between the two investment opportunities. The first investment has the leverage advantage, whereas the second investment has the advantage of being made under product cost certainty. Clearly, the seller only abandons inventories in the first-best situation if he strives for a higher investment level in the second period. As the optimal investment increases in the contribution margin, the option to reinvest is more tempting for smaller cost realizations. Contrary, reinvesting is not an option if the initial investment is already quite large or if the reinvestment is very expensive.

Also at date 1.2, the transfer quantity is determined. The efficient sales quantity given the initial investment is obtained as:

$$q_1^{ex}(I_1,\theta) \in \arg\max_{q_1}\{\Pi\} = d(\theta) + \mathrm{I}_1 . \tag{3}$$

Comparing (2) and (3), we observe that the same amount is sold in both periods, if second period sales are served from stock. The size of the initial production lot is given by:

$$\begin{aligned} r_1^{fb}(I_1,\theta) &= q_1^{ex}(I_1,\theta) + h^{fb}(I_1,\theta) \\ &= d(\theta) + I_1 + \left\{ \begin{array}{ccc} 0 & for & \dfrac{\alpha(d(\theta))^2}{2(\alpha-1)} > \dfrac{(d(\theta)+I_1)^2}{2} \\ d(\theta)+I_1 & & else \end{array} \right\}. \end{aligned} \tag{4}$$

At date 1.0, the seller chooses the initial specific investment anticipating the lot size produced subsequently. Since state θ is unknown at this time, the investment choice is made under uncertainty. Taking the probability distribution into account the seller chooses I_1^{fb}, which maximizes the firm's expected total profit.

$$I_1^{fb} \in \arg\max_{I_1}\{\Pi\}$$

The first-best level of initial investment and the resulting expected profit are presented in Lemma 1.

Lemma 1: *Under the appropriate regulatory restrictions, the first-best investment and production schedule is given as*

$$I_1^{fb} = \frac{d_h}{\alpha - 2},\ r_1^{fb} = 2 \cdot \left(d(\theta) + \frac{d_h}{\alpha - 2} \right),\ I_2^{fb} = r_2^{ex} = 0,$$

the sales and stocking volumes are

$$q_1^{ex}(I_1^{fb}, \theta) = q_2^{ex}(I_1^{fb}, \theta) = h^{fb} = d(\theta) + \frac{d_h}{\alpha - 2},$$

and the expected total profit in the first-best situation amounts to

$$\Pi^{fb} = \Pi^{ex} + \left(\frac{(d_h)^2}{2(\alpha - 2)} \right).$$

Here, $\Pi^{ex} \equiv E_\theta[(d(\theta))^2] = ⅓(d_h)^2$ represents the firm's expected total profit, if no investments are made and the corresponding ex-post efficient quantities are traded (inventory does not alter profit in absence of investments). The addend is positive. Thus, investment and inventory holding contribute positively to the firm's profits.

Lemma 1 constitutes that the initial investment is chosen sufficiently large such that it is always *ex post* rational to aggregate both periods' sales into one large production batch, irrespective of the realized state[13].

3.1. Negotiated Transfer Pricing

Consistent with the related literature the divisional managers bargain at date 1.2, and 2.2 respectively, over volume and price of the outright delivery under this pricing mechanism. Importantly, the production scheduling decision, that is the decision whether and how much inventory is build in the first cycle, is made locally at the selling division and is not subject to negotiation[14]. In absence of intra-company contracts, delivery agreements for future periods are not enforceable. In addition, the production cost after investment may fluctuate over time. Therefore, it is assumed that divisions negotiate volume and price periodically. Since bargaining takes place under symmetric information about net revenues and costs, the divisions will agree to trade the *ex post efficient* transfer quantity in each cycle, $q_1^{ex}(I_1, \theta)$ and $q_2^{ex}(I_1, h, \theta)$ respectively. These quantities maximize the contribution margin achievable from

[13] This result is generally valid for non-skewed distributions. However, for heavily skewed distributions, e.g. a two-point distribution where the low cost realization has a small *ex ante* probability, the *first-best* strategy may include a production rerun for in case the low cost is actually observed.

[14] According to Eccles (1985, p. 43) it is more accurate to think of negotiation as describing the administrative process of determining the transfer price in contrast to the price being established by a rule or calculation. The focus of negotiations is therefore clearly limited.

retail sales in a cycle. The respective margins amount to $M_1(q_1,I_1,\theta) \equiv R_1(q_1)\text{-}(c(\theta)\text{-}I_1)q_1$ in the first and to $M_2(q_2,I_2,h,\theta) \equiv R_2(q_2)\text{-}(c(\theta)\text{-}I_2)(q_2\text{-}h)$ in the second cycle.

Note that zero cost is assessed for available inventory when evaluating M_2. This is due to two reasons. First, the production cost of inventory is sunk in the second cycle. Second, in absence of alternative users of the intermediate good, inventory has no value outside the trade relationship. Thus, there is no opportunity cost assessed for inventory. For notational convenience let $M_1(I_1,\theta) \equiv M_1(q_1^{ex}(I_1,\theta),I_1,\theta)$ and $M_2(I_2,h,\theta) \equiv M_2(q_2^{ex}(I_2,h,\theta),I_2(h,\theta),h(I_1,\theta),\theta)$.

Consistent with Baldenius et al. (1999), the bargaining process is represented by a surplus-sharing rule in which the seller receives a share $\gamma \in [0,1]$ of joint gains from trade and the buyer receives the complement (1- γ). We focus on the case where γ=½, which represents the Nash bargaining solution[15]. Particularly, as the outcome of each bargaining process, the divisions agree on the delivery of q_t^{ex} and the transfer payment x_t that leaves each division with exactly half of the contribution margin, namely:

$$R_1(q_1^{ex})\text{-}\ x_1= ½\cdot M_1(I_1,\theta) \text{ and } R_2(q_2^{ex})\text{-}\ x_2= ½\cdot M_2(I_2,h,\theta).$$

At the same time it holds that:

$$x_1\text{-}[(c(\theta)\text{-}I_1)\cdot q_1^{ex}] = ½\cdot M_1(I_1,\theta) \quad (5)$$

$$x_2\text{-}[(c(\theta)\text{-}I_2)\cdot(q_2^{ex}\text{-}h)] = ½\cdot M_2(I_2,h,\theta). \quad (6)$$

The transfer payment reimburses the seller for the appropriate expenses and assigns half of the contribution margin to him. The seller is not reimbursed for money tied in inventory for the reasons mentioned before. It is easy to see that the cost of inventory is structurally equivalent to the costs for upfront relationship-specific investments: they are sunk at the time of bargaining and these costs have created value only within the relationship but not outside.

It has been pointed out in previous literature that negotiation suffers from underinvestment in cost reduction. According to (5), the seller receives only half of the surplus generated by his investment while bearing the full cost. The novelty here is that negotiation causes a reluctance to advance funds in multiple dimensions. According to (6), the

[15] The Nash bargaining solution has a natural appeal as it also emerges as the equilibrium outcome of certain non-cooperative bargaining games (cf. Fundenberg and Tirole (1991), pp. 113, and Edlin and Reichelstein (1996), Appendix A). Experimental evidence supports the view that gains tend to be split evenly in the negotiation outcome (see Luft and Libby, 1997). At the same time the experimental study of Chalos and Haka (1990) emphasizes the effect of outside opportunities on negotiation outcomes.

seller also enjoys only half the surplus generated by inventory. However, he bears the full cost for creating the inventory. The shortcoming of negotiation becomes more detrimental in the repeated model since the two assets *h* and I_1 exhibit complementarities: a higher willingness to build inventory increases the initial investment incentive and a larger initial investment increases the incentives to stock. The equilibrium investment and inventory levels are determined through backward induction.

At date 2.2, the divisions aim to maximize the firm's contribution margin given the prevailing cost of production and the inventory on hand. As stated previously, the divisions agree on the delivery of $q_2^{ex}(I_2,h,\theta)$. Interests are not conflicting with respect to the transfer quantity:

$$q_2^n(I_2,h,\theta) \in \arg\max_{q_2} \{½ \cdot M_2(q_2,I_2,h,\theta)\} = q_2^{ex}(I_2,h,\theta) \quad .$$

The divisions agree on exchanging the *ex post efficient* quantity in each state. However, this quantity may differ from the *ex post efficient* quantity traded in the first-best situation, whenever $I_2^n \neq I_2^{fb}$ or $h^n \neq h^{fb}$. As all transfers exceeding the available inventory have to be produced, it must also hold that $r_2^n(I_2,h,\theta)= r_2^{ex}(I_2,h,\theta)$.

Anticipating the subsequent production, the seller makes the cost-reducing investment at date 2.0, which maximizes his divisional cash flow in the second cycle:

$$I_2^n(h,\theta) \in \arg\max_{I_2} \{½ \cdot M_2(I_2,h,\theta) - w(I_2)\} = \begin{Bmatrix} \dfrac{d(\theta)-h}{2\alpha-1} & for \quad 0 \leq h < d(\theta) \\ 0 & for \quad d(\theta) \leq h \end{Bmatrix} \tag{7}$$

As the seller bears the entire investment cost, but can only claim half of the resulting gains, a hold-up situation exists. Comparing (7) to (1), it is easy to see that the seller underinvests from the perspective of the central office. Similar to the first-best situation, returns on the investment diminish when stocks are on hand. Thus, the optimal investment decreases in *h*. Applying forward induction we find that positive production coincides with a positive investment level:

$$q_2^n(h,\theta) = \begin{Bmatrix} \dfrac{2\alpha d(\theta)-h}{2\alpha-1} & for \quad 0 \leq h < d(\theta) \\ h & for \quad d(\theta) \leq h \end{Bmatrix} \quad . \tag{8}$$

Anticipating the course of the game given some stock level, *h*, the seller determines the following cash flow for his division in the second cycle as:

$$CF_{2,S}^{n}(h,\theta) \equiv ½ \cdot M_2(I_2^n,h,\theta) - w(I_2^n) = \begin{cases} \dfrac{h^2 + h(4\alpha \cdot c(\theta) - 2) + 2\alpha(d(\theta))^2}{8\alpha - 4} & for \quad 0 \le h < d(\theta) \\ ½h - ¼h^2 & for \quad d(\theta) \le h < 1 \\ ¼ & for \quad 1 \le h \end{cases}$$

Accordingly, at date 1.2, the seller will choose the stock level where the marginal cash flow offsets the marginal cost of inventory. To the seller the cost of inventory equals the full production cost, which depends on the initial investment as well as the state. Inventory's contribution to the seller's profit is therefore given by $CF_{2,S}^{n}(h,\theta) - (c(\theta) - I_1)h$. This function is continuous everywhere, including $h=d(\theta)$, and convex in *h* for $h<d(\theta)$ but concave for $d(\theta)\le h$. From the convexity property it follows that the optimal inventory level cannot be an interior point in the interval $[0, d(\theta)]$. That is, the seller will either stock zero inventory ($h=0$) or sufficient to satisfy second period demand entirely from stock ($h\ge d(\theta)$). In particular, the seller's expected profit is maximized for:

$$h^n(I_1,\theta) \in \arg\max_h \{CF_{2,S}^{n}(h,\theta) - (c(\theta) - I_1)h\}$$
$$= \begin{cases} 0 & for \quad \dfrac{\alpha(d(\theta))^2}{4\alpha - 2} \ge \dfrac{(2d(\theta) + 2I_1 - 1)^2}{4} \\ 2d(\theta) + 2I_1 - 1 & else \end{cases} . \tag{9}$$

The first-order condition over the concave function yields the optimal inventory level when this is positive. The contribution of that inventory level to the seller's profit yields the right-hand side of the inequality. In absence of inventories, the contribution equals the cash flow in the second cycle, which is depicted in the left-hand side of the inequality. The seller chooses the positive inventory level, if it generates a higher contribution. Note that this can only apply if $2d(\theta)+2I_1-1>d(\theta)$ is satisfied. Also at date 1.2., the two divisions agree on the first transfer quantity:

$$q_1^n(I_1,\theta) \in \arg\max_{q_1} \{½ \cdot M_1(q_1,I_1,\theta\} = q_1^{ex}(I_1,\theta) = d(\theta) + I_1.$$

Similar to the second cycle, interests do not conflict when setting this parameter. Again, the divisions trade the *ex post* efficient quantity, which may not equal the ex post efficient quantity of the first-best solution, if $I_1^n \neq I_1^{fb}$. The production batch in the first period, which consists of outright sales as well as goods made to stock amounts to

$$r_1^n(I_1,\theta) = q_1^{ex}(I_1,\theta) + h^n(I_1,\theta)$$
$$= d(\theta) + I_1 + \begin{Bmatrix} 0 & \text{for} \quad \dfrac{\alpha(d(\theta))^2}{4\alpha-2} \geq \dfrac{(2d(\theta)+2I_1-1)^2}{4} \\ 2d(\theta)+2I_1-1 & \text{else} \end{Bmatrix}$$

At date 1.0, the seller makes the initial investment. The investment incentive increases in the production lot produced in the first cycle. The investment decision is made under uncertainty. Respecting the state probabilities, the seller chooses the investment, which maximizes his expected profit after both trades:

$$I_1^n \in \arg\max_{I_1} \left\{ E_\theta\left[½ \cdot M_1(I_1,\theta) + CF_{2,S}^n(h^n(I_1,\theta),\theta) - (c(\theta)-I_1)h^n(I_1,\theta)\right] - w(I_1)\right\} \quad .$$

The initial investment chosen by the seller under negotiation as well as the resulting expected profit are presented in Lemma 2.

Lemma 2: *Under the appropriate regulatory restrictions, the investment and production schedule under negotiated transfer pricing is given as*

$$I_1^n = E_\theta[I_2^n] = \frac{d_h}{4\alpha-2},\ I_2^n = \frac{d(\theta)}{2\alpha-1},\ r_1^n = E_\theta[r_2^n] = d(\theta) + \frac{d_h}{4\alpha-2},\ r_2^n = d(\theta) + \frac{d(\theta)}{2\alpha-1},$$

the sales and stocking volumes are

$$q_1^n = E_\theta[q_2^n] = d(\theta) + \frac{d_h}{4\alpha-2}\ , q_2^n = d(\theta) + \frac{d(\theta)}{2\alpha-1}\ , h^n = 0,$$

and the expected total profit in the first-best situation amounts to

$$\Pi^n = (d_h)^2 \cdot \frac{32\alpha^2 - 11\alpha + 1}{24(2\alpha-1)^2} \quad .$$

Lemma 2 constitutes that inventory is never held under negotiated transfer pricing irrespective of the state realization. The initial investment is chosen insufficiently to render stockkeeping an *ex post efficient* choice. Instead, the seller produces periodically, which separates the two cycles. The production quantity matches the transfer volume period by period. Implicitly, the investment, production and transfer volumes of each period correspond to the equilibrium levels determined by Baldenius et al. (1999) for the nonrecurring game. In contrast to the first cycle, the seller is able to adjust the second investment to the prevailing state. However, the two investment levels are equal in expectation from an *ex ante* perspective.

3.2 Cost-based Transfer Pricing

Under this mechanism, the seller quotes a unit cost, v_t, in each period, which serves as the transfer price. The buyer chooses his periodic order according to the prevailing transfer price. The resulting transfer payment in each period is $x_t= v_t \cdot q_t(v_t)$. The seller effectively has monopoly power in the presence of unobservable and non-verifiable production costs. This intentionally ignores limits for overstating costs to capture the main criticism of standard costs that either party is interested in biasing the cost report. In each cycle, the transfer quantity ordered by the buyer is given as $q_t(v_t) \in \arg\max_{qt}\{R(q_t)- v_t \cdot q_t\}=1- v_t$.

At date 2.2, the seller quotes the following cost v_2 anticipating the buyer's order:

$$v_2(I_2,h,\theta) \in \arg\max_{v2}\{v_2 \cdot q(v_2) - (q(v_2) - h) \cdot (c(\theta) - I_2)\}$$
$$= \begin{Bmatrix} ½(1 + c(\theta) - I_2) & for & 0 \le h < q(v_2) \\ 1-h & for & q(v_2) \le h < ½ \\ ½ & for & ½ \le h \end{Bmatrix}.$$

The seller's objective is to maximize the transfer payment net production cost. The inventory value generally does not affect the quote as long production is maintained in the second cycle. If inventories are sufficiently large to serve second period demand exclusively from stock, the seller quotes a price at which inventory is fully liquidated. However, the seller will only liquidate stock levels up to one half to avoid negative marginal returns. Directly from the quoted cost follows the production lot

$$r_2^c(I_2,h,\theta) = (1-v_2) - h = \begin{Bmatrix} ½\big(d(\theta)+I_2\big) - h & for & 0 \le h < ½\big(d(\theta)+I_2\big) \\ 0 & for & ½\big(d(\theta)+I_2\big) \le h \end{Bmatrix}.$$

At date 2.0, the seller chooses I_2 to reduce the production cost of the second cycle, which maximizes his divisional cash flow in the second period, which are the transfer payment net the costs of production and investment:

$$I_2^c(h,\theta) \in \arg\max_{v2}\{v_2 \cdot q(v_2) - (q(v_2) - h)(c(\theta) - I_2) - w(I_2)\} =$$
$$\begin{Bmatrix} \dfrac{d(\theta) - 2h}{2\alpha - 1} & for & 0 \le h < ½d(\theta) \\ 0 & for & ½d(\theta) \le h \end{Bmatrix}.$$

Applying forward induction we find that production is positive if and only if investment is positive. In particular it holds that

$$r_2^c(h,\theta) = \begin{Bmatrix} \dfrac{\alpha(d(\theta) - 2h)}{2\alpha - 1} & for & 0 \le h < ½d(\theta) \\ 0 & for & ½d(\theta) \le h \end{Bmatrix}.$$

Substituting the subsequent decisions into the seller's second period cash flow yields:

$$CF_{2,S}^c(h,\theta) \equiv v_2 \cdot q(v_2) - (q(v_2) - h)(c(\theta) - I_2) - w(I_2)$$
$$= \begin{Bmatrix} \dfrac{2h^2 + h(4\alpha \cdot c(\theta) - 2) + \alpha(d(\theta))^2}{4\alpha - 2} & for & 0 \le h < ½d(\theta) \\ h - ½h^2 & for & ½d(\theta) \le h < ½ \\ ¼ & for & ½ \le h \end{Bmatrix}.$$

At date 1.2, the seller chooses the inventory amount such that marginal second period cash flow offsets the marginal cost of production:

$$h^c(I_1,\theta) \in \arg\max_h \{CF_{2,S}^c(h,\theta) - (c(\theta) - I_1)h\}$$
$$= \begin{Bmatrix} 0 & for & \dfrac{\alpha(d(\theta))^2}{4\alpha - 2} \ge \dfrac{(d(\theta) + I_1)^2}{4} \\ ½(d(\theta) + I_1) & & else \end{Bmatrix}.$$

The objective function is continuous everywhere and concave for $h<½d(\theta)$ but convex for $h>½d(\theta)$. From this we conclude that either no inventory is build ($h^c=0$) or sufficient to satisfy the entire demand in the second period ($h^c>½d(\theta)$). The first-order condition of the concave part yields the optimal inventory level when this is positive. The contribution of this inventory level to the seller's profit is merged in the right-hand side of the inequality. In absence of inventories, the contribution is equivalent to the cash flow in the second cycle, which is depicted in the left-hand side of the inequality. The seller chooses the positive inventory level, if and only if it generates a higher contribution. Note that h^c=½($d(\theta)$+I_1) implies h^c>½$d(\theta)$ for all I_1>0.

Also at date 1.2, the claims the initial cost v_1, which maximizes the transfer payment net production cost anticipating the buyer's response order of $q_1(v_1)$=1- v_1:

$$v_1(I_1,\theta) \in \arg\max_{v2}\{(v_1 - c(\theta) + I_1)q(v_1)\} = ½(1 + c(\theta) - I_2).$$

The size of the initial production is given by:

$$r_1^c(I_1,\theta) = q_1^c(I_1,\theta) + h^c(I_1,\theta) = \frac{d(\theta)+I_1}{2} + \begin{cases} 0 & \textit{for} \quad \frac{\alpha(d(\theta))^2}{4\alpha-2} \geq \frac{(d(\theta)+I_1)^2}{4} \\ ½(d(\theta)+I_1) & \textit{else} \end{cases}.$$

At date 1.0, the seller chooses the initial investment anticipating the lot size produced subsequently. Taking the probability distribution for the state variable into account the seller chooses the investment which maximizes the expected profit of his division.

$$I_1^n \in \arg\max_{I_1}\{E_\theta[(v_1 - c(\theta) + I_1)(1 - v_1) + CF_{2,S}^n(h^c(I_1,\theta),\theta) - (c(\theta) - I_1)h^c(I_1,\theta)] - w(I_1)\}. \tag{10}$$

The initial investment chosen by the seller under cost based transfer pricing as well as the resulting expected profit are presented in Lemma 3.

Lemma 3: *Under the appropriate regulatory restrictions, the investment and production schedule under cost-based transfer pricing is given as*

$$I_1^c = \frac{d_h}{2\alpha-2},\ r_1^c(\theta) = \left(d(\theta) + \frac{d_h}{2\alpha-2}\right),\ I_2^c = r_2^c = 0,$$

quoted costs as well as sales and stocking volumes are

$$v_1(\theta) = v_1(\theta) = \frac{1}{2}\left(1 + c(\theta) + \frac{d_h}{2\alpha-2}\right), q_1^c(\theta) = q_2^c(\theta) = h^c(\theta) = \frac{1}{2}\left(d(\theta) + \frac{d_h}{2\alpha-2}\right),$$

and the expected total profit of the firm under cost-based transfer pricing amounts to:

$$\Pi^c = (d_h)^2 \cdot \left(\frac{2\alpha-1}{4(\alpha-1)}\right)^2.$$

3.3. Comparison of negotiated and cost-based transfer pricing

At date 0, the head-office chooses the transfer pricing mechanism. In particular, it chooses:

$$\begin{Bmatrix} \text{cost-based} & \text{for} & \Pi^c > \Pi^n \\ \text{either} & \text{for} & \Pi^c = \Pi^n \\ \text{negotiation} & \text{for} & \Pi^c < \Pi^n \end{Bmatrix}.$$

Taking the values for Π^n and Π^c from Lemma 2 and Lemma 3, we can rearrange the condition for the head-office to implement cost-based transfer pricing to:

$$\Pi^c > \Pi^n \Leftrightarrow$$
$$(d_h)^2 \cdot \left(\frac{2\alpha - 1}{4(\alpha - 1)}\right)^2 > (d_h)^2 \cdot \frac{32\alpha^2 - 11\alpha + 1}{24(2\alpha - 1)^2} \Leftrightarrow \frac{(2\alpha - 1)^2}{4(2\alpha - 2)^2} > \frac{8(2\alpha - 1)^2 + 7(3\alpha - 1)}{24(2\alpha - 1)^2}. \quad (11)$$

The condition is fully described by the investment cost parameter α. However, the distribution of cost states has an indirect impact on the mechanism choice via the regulatory condition, $\alpha>1+1/c_l$. Solving the inequality in (11) for α yields an unhandy solution, for this we omit the expression here. It is easy to see, however, that the nominator as well as the denominator is larger on the right-hand side. Further, the nominators and denominators of both sides are positive and increasing in α. Thus, there exists a threshold value, α^*, for which cost-based is chosen if $\alpha<\alpha^*$ applies. In other words, cost-based transfer pricing outperforms negotiation when investments are inexpensive, that is if investments contribute significantly to the overall profit. In practice, for example, this may especially apply for capital intensive industries.

Under the regulatory condition, $\alpha>1+1/c_l$, the assumption $\alpha<\alpha^*$ implies threshold values for the lowest $c_l>c_l^*$ and $d_h<d_h^*$. That is, the highest realizable retail margin must not exceed a certain threshold or else cost-based pricing cannot outperform. Saying it differently, the *ex ante* retail margin has to be relatively thin for cost-based pricing to be the mechanism of choice. In practice this may hold for industries that are highly competitive (on the retail level). We can approximate $\alpha^*\approx2.42$, which implies $c_l^*\approx0.7$ and $d_h^*\approx0.3$. Thus, the requirement is not very strong given a maximal retail price of 1.

To make a conjecture in which industries we would expect to see cost-based rather than negotiated transfer pricing, we predict that the former will prevail in capital-intensive industries facing intense competition on the retail level. One example would be the food processing industry, which exhibits these characteristics (cf. van Donk, 2001).

Comparing parameter values reveals other interesting relations. On the one hand, larger investments are made under cost-based transfer pricing ($I^c{}_1 > I^n{}_1$). This observation could not be made by Baldenius et al. (1999), because the distorted transfer quantity curtailed investment incentives under cost-based pricing. We are able to insulate this effect in our model. On the other hand, the harmful double-marginalization effect observed for cost-based pricing is retained in our model. That is, the trade volumes are always higher for negotiation ($q^n{}_1 = q^n{}_2 > q^n{}_1 = q^n{}_2$).

At last let us briefly turn to our model assumptions, how these drive the race between the two transfer pricing mechanisms. We assumed that periodic production in small batches enjoys the flexibility to revamp production and fit the investment to the prevailing state. This advantage is more pronounced the higher uncertainty is ex ante. Since the seller opts for this production schedule under negotiation, this mechanism is more competitive when uncertainty (the variance of the state distribution) is high. For our uniform distribution the variance is $var(d(\theta)) = (d_h)^2/12$. Choosing a different distribution with a higher variance may cause negotiation to be strictly superior to cost-based transfer pricing. This applies in particular for a two-point distribution over $d \in \{0, d_h\}$ with equal probabilities, where the variance is $(d_h)^2/4$, i.e. three times the variance of the continuous distribution.

4. Conclusion

Based on a non-recurrent model Baldenius et al. (1999) find that negotiation dominates cost-based transfer pricing. The caveat of this finding is its inconsistency with empirical observations, which proclaim the widespread use of cost-based transfer pricing (cf. Eccles 1985). The inconsistency led Baldenius and Reichelstein (1998) to emphasize that the implementation of cost-based transfer pricing cannot be ascribed to the hold-up problem (p. 254).

In this article we work to dispel this inconsistency. We show that the implementation of cost-based transfer pricing is in fact compatible with the hold-up problem. In particular, we base our research on a repeated model of incomplete contracting in which inventories can be employed to exploit scale effects. We find that the cost-based mechanism may outperform negotiation in the repeated model. The result is driven by the seller’s reluctance to build inventory under negotiation. Inventory, while contributing positively to the firm’s success, tie capital. If the intra-firm buyer is the only user of the intermediate good, the capital tied in inventory is *relationship-specific*. Thus, a hold-up problem exists with respect to stockkeeping. This hold-up problem complements the conventional hold-up problem for upfront investments. In a nutshell, the hold-up problem is more pronounced in the extended model. Since negotiation is prone to the hold-up problem, its relative performance is weaker in the repeated model. This causes the breach of the dominance relationship.

It is important to realize that this finding is highly constructive. While the dominance relationship seemed incompatible with empirical observations, our finding builds a bridge between the analytical work of Baldenius et al. (1999) and the empirical data. On the one hand, for example, our analysis provides room for the superiority of cost-based transfer pricing. On the other hand it accommodates the dominance relationship if stockkeeping is infeasible.

Since our analysis yields a horse-race between the two transfer mechanisms rather than a dominance relationship, we are able to conduct a sensitivity analysis with respect to the exogeneous parameters. This allows us to conjecture the determinants for implementing a particular transfer price in practice. In particular, we find that cost-based transfer pricing outperforms negotiation when investment costs are low, that is when investment contributes significantly to overall profits, and if retail margins are thin. In contrast, negotiation is the superior pricing mechanism if the opposite holds.

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APPENDIX:

Proof of Lemma 1

Following the procedure outlined in the article, we obtain that second period sales are either entirely served from stock or produced in the second period. While serving second period sales from stock contributes $\frac{(d(\theta)+I_1)^2}{2}$ to the total profit, $\frac{\alpha(d(\theta))^2}{2(\alpha-1)}$ is contributed by a repeated production run. The HQ will opt for whatever turns out greater given the cost realization. This is summarized in equation (2). Rearranging the inequality, inventory is not built if and only if $I_1 < d(\theta)\cdot \mathrm{K}$ with $\mathrm{K} \equiv \sqrt{\frac{\propto}{\propto-1}}-1$. Note that K is positive for all α>1. That is, if I_1 is chosen *ex ante* such that $I_1 < d_h \mathrm{K}$, then inventory may be held *ex post* in some but not all states. However, if some $I_1 \geq d_h \mathrm{K}$ is chosen, inventory will be built in all possible states. The effect of I_1 on future strategies will be accounted for under rational expectations. Thus, the initial investment affects the first sales quantity, the probability to carry inventory as well as the second sales quantity if the latter is served from stock. The first-best initial investment maximizes the expected total profit, $I_1^{fb} \in \arg\max_{I_1}\{\Pi\}$. Taking the distribution of $d(\theta)$ into account, with $d(\theta)$~U[0,d_h] and probability density function $\phi(d(\theta))=1/d_h$, , the expected total profit is given as:

$$\Pi = \begin{cases} \frac{1}{d_h}\left[\int_0^{d_h}\frac{(x+I_1)^2}{2}dx + \int_0^{\frac{I_1}{\mathrm{K}}}\frac{(x+I_1)^2}{2}dx + \int_{\frac{I_1}{\mathrm{K}}}^{d_h}\frac{\alpha\cdot x^2}{2(\alpha-1)}dx\right] & for \quad I_1 < d_h\mathrm{K} \\ \frac{1}{d_h}\left[\int_0^{d_h}(x+I_1)^2 dx\right] & for \quad I_1 \geq d_h\mathrm{K} \end{cases} - \frac{\alpha(I_1)^2}{2}.$$

The upper case comprises the expected profit when inventory may not be built in all states. The function consists of three components. The first component represents the contribution of sales in the first cycle. The second corresponds to the contribution of sales in the second cycle when inventory holding is *ex post* optimal. The third component represents the cash flow net reinvestment expenses in the second cycle when a rerun of production is *ex post* optimal. The lower case corresponds to the expected total profit, if the initial investment is large enough to make stockpiling an *ex post* dominant strategy. In either case investment costs are incurred. Taking derivatives we get:

$$\frac{\partial \Pi}{\partial I_1} = \begin{cases} I_1^{\,2}\left(\frac{3\alpha-1}{\alpha-1} - 3\sqrt{\frac{a}{a-1}}\right)\cdot\frac{1}{2d_h\mathrm{K}^3} - I_1(\alpha-1) + \frac{d_h}{2} & for \quad I_1 < d_h\mathrm{K} \\ -I_1(\alpha-2) + d_h & for \quad I_1 \geq d_h\mathrm{K} \end{cases}.$$

The case differentiation with respect to the derivatives allows a detailed description of the behavior of the (expected) profit function. Over the interval $I_1<d_hK$ the marginal profit increases *quadratically* in I_1. Note that the factor is positive for positive values of α. This is accompanied by a *linear* decrease driven by investment costs. From this we conclude that a (local) maximum cannot be found at any interior point $I_1<d_hK$, because no interior point meets the condition that smaller as well as larger investment levels both create smaller function values. Thus, the maximum must lie in the latter interval $I_1\geq d_hK$. Solving the first order condition yields:

$$I_1^{fb} = \frac{d_h}{\alpha-2}. \tag{A.1}$$

We can easily validate that this solution is feasible, i.e. $d_h/(a\text{-}2)\geq d_hK$. In particular this proves that inventory-holding is *ex post* efficient in every state. Directly from (A.1) follows the regulatory requirement. To ensure non-negative production costs in all states we require $c_l\text{-}I_1^{fb}\geq 0$, which reduces to $\alpha\geq 1+1/c_l$. Forward induction yields:

$$h_1^{ex}(I_1,\theta) = q_1^{ex}(I_1,\theta) = \frac{d_h}{\alpha-2} + d(\theta) \text{ and } r_1^{ex}(I_1,\theta) = 2\cdot\left(\frac{d_h}{\alpha-2} + d(\theta)\right).$$

From substitution and simplification we get:

$$\Pi^{fb} = \frac{d_h^{\,2}(2\alpha-1)}{6(\alpha-2)}.$$

This concludes the proof of Lemma 1.

Proof of Lemma 2

The proof is structured as follows. First we proof why carrying inventory cannot be an ex post efficient strategy under negotiated transfer pricing in any state. Second we determine the optimal level of initial investment presuming the absence of inventory. At last, we derive the optimal parameter values and profits under negotiated transfer pricing through forward induction.

Following the procedure outlined in the article, we obtain that second period sales are either entirely served from stock or produced in the second period. Whether or not a positive inventory level is chosen depends on the outcome of the objective function given by (9). As outlined in the article, this function is continuous everywhere and convex in h for $h<d(\theta)$ but concave for $d(\theta)>h$. Taking derivatives, it can easily be shown that the function is strictly decreasing in h over the entire range (including the convex as well as the concave part) when $I_1<½c(\theta)$ holds. Consequently, this is a sufficient condition for holding zero inventory (h^n=0).[16]

Since $I_1<½c(\theta)$ is a sufficient condition for the seller to turn down the stocking opportunity *ex post*, the rational seller anticipates that he will not build inventories in any state, if his initial investment satisfies $I_1<½c_l$ *ex ante*. We will now proof by contradiction that $I_1^n<½c_l$ holds: Assume $I_1^n\geq½c_l$ holds. Further we assume the regulatory condition, $c_l>I_1^{fb}$ holds. Combining the two we get $I_1^n>½I_1^{fb}$, which yields a contradiction. If the seller receives only half the surplus from the investment but bears the full cost under negotiated transfer pricing, the investment incentives are insufficient for him to make an investment of the required magnitude. This proofs that it is always *ex post efficient* to rerun production in the second cycle under negotiation in every state.

Setting $h^n(I_1,\theta)$=0 for all θ and taking the distribution of $d(\theta)$, with $d(\theta)$~U[0,d_h] and probability density function $\phi(d(\theta))=1/d_h$, into account, the seller's expected total profit reduces to:

$$\Pi_S=\frac{1}{d_h}\left[\int_0^{d_h}\frac{(x+I_1)^2}{4}dx+\int_0^{d_h}\frac{\alpha\cdot x^2}{4\alpha-2}dx\right]-\frac{\alpha(I_1)^2}{2}\ \text{ for } I_1\leq ½c_l \quad .$$

[16] For $I_1>½c(\theta)$ the objective function initially decreases in h but increases for larger values of h. A sufficient condition for inventories to be held in optimum is given by $I_1>(2c(\theta)(\alpha\text{-}1)+1)/(4\alpha\text{-}2)$. This ensures that the objective function is strictly increasing for $h<d(\theta)$.

The first order condition with respect to I_1 yields:

$$I_1^n = \frac{d_h}{4\alpha - 2}.$$

It can easily be verified that $I_1^n \leq ½c_l$ is consistent with the regulatory condition. Forward induction yields the value for q_1^n and r_1^n. Substituting h^n=0 into (8) and (7) yield the values for I_2^n and q_2^n as stated in the lemma from which r_2^n follows.

The firm-wide profit is the sum of the divisional profits. The joint profit in each cycle is the entire contribution margin of sales net the investment cost borne by the seller. The firm profit amounts to

$$\Pi = \Pi_S + \Pi_B = \frac{1}{d_h}\left[\int_0^{d_h} \frac{(q_1^n(x))^2}{2} dx + \int_0^{d_h} \left(\frac{(q_2^n(x))^2}{2} - \frac{\alpha(I_2(x))^2}{2} \right) dx \right] - \frac{\alpha(I_1)^2}{2} \tag{A.2}$$

$$= \frac{d_h^2 \cdot \left(16\alpha^2 - 7\alpha + 1\right)}{24(2\alpha - 1)^2} + \frac{d_h^2 \cdot \left(16\alpha^2 - 4\alpha\right)}{24(2\alpha - 1)^2}. \tag{A.3}$$

Substituting for q_1^n, q_2^n, I_1^n, and I_2^n allows us to rewrite (A.2) as (A.3). The first term in (A.3) is the joint contribution margin net investment cost in the first cycle and the second term that of the second cycle. The second term is larger, because certainty enables higher profits in the second period. Simplifying (A.3) we obtain the firm profit as:

$$\Pi = \frac{d_h^2 \cdot \left(32\alpha^2 - 11\alpha + 1\right)}{24(2\alpha - 1)^2}.$$

This concludes the proof of Lemma 2.

Proof of Lemma 3

The proof proceeds similar to the other two. First, we proof that stocking is always *ex post efficient* under cost-based transfer pricing in any state. Second, we derive the initial investment chosen presuming inventory is held in any state. Last, we derive the function values and the firm-wide profit via forward induction.

The proof that stocking is ex post efficient proceeds similarly to the proof in the first-best situation. Following the procedure outlined in the article, we obtain that second period sales are either entirely served from stock or produced in the second period. While serving second period sales from stock contributes $\frac{(d(\theta)+I_1)^2}{4}$ to the seller's profit, $\frac{\alpha(d(\theta))^2}{4\alpha-2}$ is contributed by a repeated production run. The seller will opt for whatever turns out greater given the cost realization. Rearranging this condition yields that inventory is not built if and only if $I_1 < d(\theta)\cdot H$ with $\mathrm{H} \equiv \sqrt{\frac{2\alpha}{2\alpha-1}} - 1$. Note that H is positive for all α>1. That is, if I_1 is chosen *ex ante* such that $I_1 < d_h H$, then inventory may be held *ex post* in some but not all states. However, if some $I_1 \geq d_h H$ is chosen, inventory will be built in all states. The effect of I_1 on future strategies will be accounted for under rational expectations. Thus, the initial investment affects the first sales quantity, the probability to carry inventory as well as the second sales quantity if the latter is served from stock. The initial investment is determined as in (10). Taking the distribution of $d(\theta)$ into account, with $d(\theta)$~U[0,d_h] and probability density function $\phi(d(\theta))=1/d_h$, , we can write (10) as:

$$\Pi_S^c = \begin{Bmatrix} \frac{1}{d_h}\left[\int_0^{d_h}\frac{(x+I_1)^2}{4}dx + \int_0^{\frac{I_1}{H}}\frac{(x+I_1)^2}{4}dx + \int_{\frac{I_1}{H}}^{d_h}\frac{\alpha\cdot x^2}{4\alpha-2}dx\right] & for \quad I_1 < d_h H \\ \frac{1}{d_h}\left[\int_0^{d_h}\frac{(x+I_1)^2}{2}dx\right] & for \quad I_1 \geq d_h H \end{Bmatrix} - \frac{\alpha(I_1)^2}{2}. \quad \text{(A.4)}$$

The upper case comprises the expected profit when inventory may not be built in all states. The function consists of three components. The first component represents the seller's contribution of sales in the first cycle. The second corresponds to the contribution of sales in the second cycle when inventory holding is *ex post* optimal. The third component represents the cash flow of the seller net reinvestment expenses in the second cycle when a rerun of production is *ex post* optimal. The lower case corresponds to the seller's expected profit, if the initial investment is large enough to make stockpiling an *ex post* dominant strategy. In either case investment costs are incurred.

For the case where inventory is held in some but not all states, $I_1<d_hH$, we observe that I_1 expands the domain of the second term while reducing the domain of the third term at the same time. In addition, the function of the second term increases quadratically in I_1, while the function of the third is constant in I_1. Integrating reveals that the seller's profit increases cubically in I_1, which stands vis-à-vis the quadratic costs of I_1. Consequently, no investment satisfying $I_1<d_hH$ can yield a (local) maximum to the seller's expected profit function. Therefore the maximum must be found at some $I_1 \geq d_hH$. The latter part of the function is concave in I_1. We receive the optimal investment from the first-order condition:

$$I_1^c = \frac{d_h}{2\alpha - 2}. \tag{A.5}$$

All parameter values stated in Lemma 3 follow directly by forward induction. Substituting I_1^c in (A.4), we receive the seller's expected profit under cost-based transfer pricing. The buyer's cash flow in period t is given by $CF_{t,B}^2= R(q_t)- v_t \cdot q_t$, which reduces to $CF_{t,B}^2=½(q_t)^2$ for $q_t=1-v_t$ and the prevailing revenue function. Inserting $q_t^c=½(d(\theta)+I_1)$ we obtain $CF_{t,B}^c=⅛(d(\theta)+I_1)^2$ and $\Pi_B^c=CF_{1,B}^c+CF_{2,B}^c=¼(d(\theta)+I_1)^2$. Adding this to the seller's profit in (A.4) we derive the function of the expected firm-wide profit as:

$$\Pi^c = \Pi_S^c + \Pi_B^c = \frac{1}{d_h}\left[\int_0^{d_h} ¾(x+I_1)^2\,dx\right] - ½\alpha(I_1)^2 \quad for \quad I_1 \geq d_hH. \tag{A.6}$$

Substituting (A.5) into (A.6) we derive the firm-wide expected profit under cost-based transfer pricing:

$$\Pi^c = (d_h)^2 \cdot \left(\frac{2\alpha - 1}{4(\alpha - 1)}\right)^2.$$

This concludes the proof of Lemma 3.