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INCENTIVE COMPATIBILITY OF DUAL TRANSFER PRICING

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Abstract

We examine the implementation of efficient decisions about accepting a special order with asymmetric information by means of a dual transfer pricing mechanism based on Ronen and McKinney (1970). The model is designed in a simple fashion, two vertically related divisions within a firm (manufacturing and distribution) process a special order of a single product. Each division manager has private information about the divisional parameters (production costs and profit margin) and both report simultaneously to the other manager. The reports mutually affect the managers' payoffs by determining the transfer payments which are payed to both divisions. Subsequently, based on the reports, the principal decides if the special order will be accepted. The outcome of this model is that cheating is a Bayes-Nash equilibrium and is Pareto-efficient, but truth-telling is a dominant strategy incentive-compatible equilibrium and strongly risk-dominates cheating. When adding an additional stage to the game, the accounting stage, it becomes clear that the incentives are inverse to those in Ronen and McKinney (1970) as the incentives to cheat disappear. The reason is that the managers only receive the "award" from cheating if they indicate the true information in the accounting stage. If they choose to report untruthfully then they suffer a loss as they need to pay the difference between the true and the incorrectly accounted value out of their own pocket. It follows that this model design is more robust against cheating than the introduction of a penalty, as studied by Ronen (1992). Therefore, dual transfer prices are able to implement the first-best solution. These results also clearly disprove the main results of Wagenhofer (1994).

1. Introduction

We study the incentive compatibility of dual transfer prices in an agency-based transfer pricing model according to the seminal article of Ronen and McKinney (1970). The dual transfer pricing scheme makes use of two separate pricing methods to price each interdivisional transaction. Ronen and McKinney have shown that efficient decisions are implementable if the manufacturing division is credited the average profit margin and if the distribution division is debited the average manufacturing costs.

The issue of managerial behavior within an operational network of departments, relations and decisions is still relevant and worth to revisit. The predominant problem is the existence of private information on the part of the managers of the operational units. If mutually dependent decisions are associated with uncertainty, the problem of cheating agents with private information emerges. In order to solve this problem, a mechanism is needed that deters the agents from cheating. This ideal is known as the first-best solution, and it has been shown that the Groves mechanism is able to overcome the information asymmetry in many scenarios. We use Wagenhofer's simplified framework of the Ronen/McKinney model and the Groves payoff scheme (Groves and Loeb 1976, 1979) to solve the problem of information asymmetry in a production company with two vertically related divisions.

Some other articles have investigated similar scenarios and proposed different solutions for realizing incentive compatibility. Ronen (1992) suggested including a penalty factor in the Ronen/McKinney model in order to avoid collusion on the part of the agents. Without the penalty, agents are expected to cheat due to the existence of multiple Bayes-Nash equilibria. Avila and Ronen (1999) show in an experimental framework that the modified model incites the agents to behave more truthfully *with* than *without* the penalty factor.

We study the dual transfer pricing rule in a slightly different model. A principal decides upon accepting or rejecting a one-time only special order when the production capacity is idle and the order has no long-run implications. The principal has no information concerning the realized costs of the production unit and the profit margin of the distribution division. The division managers have private information and announce the marginal costs and the profit margin simultaneously. Our analysis enlarges and refines the framework used in Wagenhofer (1994) to show that dual transfer prices are still incentive-compatible in various settings and induce efficient decisions and outcomes. Our findings also disprove Wagenhofer result that the dual transfer pricing rule is unable to induce efficient decisions, if collusion among agents cannot be prevented.

Our analysis shows that both cheating and truth-telling are Bayes-Nash equilibria, but only truth-telling is an equilibrium in dominated strategies and is therefore incentive-compatible if collusion cannot be enforced. Insofar, the game contains elements of the prisoners' dilemma, and truth-telling constitutes the threat-point.

It is often argued that the dual transfer pricing mechanism is susceptible to collusions in the long-run. Therefore, we have modified the mechanism in our model by changing the transfer prices. This mechanism is similar to the penalty rule of Ronen (1992) and rules out the cheating equilibrium. However, in contrast to Ronen (1992), the managers are forced to indicate true information in our model in the last stage of the game, the accounting stage. The reason is that the managers in our model tend to underestimate the costs and exaggerate the profit as opposed to the managers in the Ronen model. Consequently, they have to pay the difference to the untrue value if they decide to indicate untrue values in the accounting. This finding is presented in section 6 where we modify the traditional pricing scheme in order to achieve more strict incentives for truthful reporting. This makes truth-telling the only attractive strategy.

In the following section we introduce notations and define the equilibrium concept of Bayes-Nash. We then present the game's solution in sections 3 and 4. In section 5 we solve the model in different scenarios before presenting the modified pricing scheme in section 6.

2. Notations and the basic framework

Let the relevant costs in the manufacturing division be θ_1 drawn from the finite set $\theta_1 \in K = \{k_L, k_H\}$, where *L* denotes low and *H* high level. The profit margin of the distribution division from the special order is $\theta_2 \in D = \{d_L, d_H\}$. Throughout most sections of the article we assume the following relation between states: $k_L < d_L < k_H < d_H$, which is common knowledge among the agents and the principal. In sections 6, 7, and 8 other relations are used, which is explained in the respective sections.

Information about the divisional costs and the profit margin is privately distributed among the division managers. Assume that the prior probability of agent *i*'s type, $\rho(\theta_i)$ with $\sum_{\theta_1 \in K} \rho(\theta_1) = 1$ and $\sum_{\theta_2 \in D} \rho(\theta_2) = 1$ for all $i \in \{1,2\}$, is strictly positive and common knowledge and let $F(\theta_1, \theta_2) = \rho(\theta_1) \cdot \rho(\theta_2)$ be the joint probability distribution of the agents' types. The common knowledge hypothesis ensures that both agents are able to compute the consequences of their behavior (Harsanyi, 1967-68). $\rho_i\left(\theta_{-i} \middle| \tilde{\theta}_{-i}\right)$ denotes agent *i*'s belief concerning her[1] opponent's type θ_{-i} on condition that she chooses $\tilde{\theta}_{-i}$ derived by Bayes' rule.

The course of action is as follows: after nature determines the types of the agents, both agents report on their parameters: manufacturing costs and profit margin respectively. In the third stage of the game, based on the reports, the principal decides whether the special order will be accepted and carried out. If the order has been carried out the agents are paid off based on their divisional profits, which in turn result from the agents' accounting entries of their reported parameters. If the principal deprecates the accomplishment of the order, neither the agents nor the principal (i.e. the firm) receive a payoff.

Agents are assumed to be risk-neutral. The decision rule regarding the special order is specified by a mapping $s_P\left[\tilde{\theta}_1,\tilde{\theta}_2\right]$, which assigns a value of $s_P = 1$, if $\tilde{\theta}_2 - \tilde{\theta}_1 > 0$, and a value of $s_P = 0$, if $\tilde{\theta}_2 - \tilde{\theta}_1 < 0$, to any combination of types $\left(\tilde{\theta}_1,\tilde{\theta}_2\right)$.[2] Let us assume that the divisions earn hypothetical profits resulting from the special order, from which the agents' payoffs are derived. The manufacturing (distribution) division's hypothetical profit is $\pi_1 = s_P\left[\tilde{\theta}_2 - \theta_1\right]$ ($\pi_2 = s_P\left[\theta_2 - \tilde{\theta}_1\right]$), if the corresponding manager's state of nature is θ_i, she reports $\tilde{\theta}_i$ and the other manager reports $\tilde{\theta}_{-i}$, which depends on each manager's own type and on the strategies played.[3] The transfer payment equals the value of the other manager's report, which captures the notion of dual transfer pricing. We assume that the agents receive a remuneration depending on the success of their own divisions. Thus, the agents' utility payoffs are assumed to be derived from the hypothetical divisional profits in the form of a monotonic transformation indicated by $u_i\left(\tilde{\theta}_{-i},\tilde{\theta}_i \middle| \theta_i\right) = \phi[\pi_i]$. A profile of strategies is compatible with Bayesian incentives, if the following condition holds true:

$$E_i\left[u_i\left(\theta_{-i},\theta_i \middle| \theta_i\right)\right] \geq E_i\left[u_i\left(\theta_{-i},\tilde{\theta}_i \middle| \theta_i\right)\right] \qquad (1)$$

for all $\tilde{\theta}_i$, $\tilde{\theta}_{-i}$, θ_i, θ_{-i} and i, where $E_i = \sum u_i\left(\theta_i,\theta_{-i} \middle| \theta_i\right)\rho_i\left(\theta_{-i} \middle| \tilde{\theta}_{-i}\right)$. In the next section we examine the agents' optimal responses.

3. Agents' incentives under information asymmetry

The game takes the form of an extensive game since an information set for agent i consists of more than one decision node. We choose the standard form, for simplicity, to represent the game, as depicted in the figure.

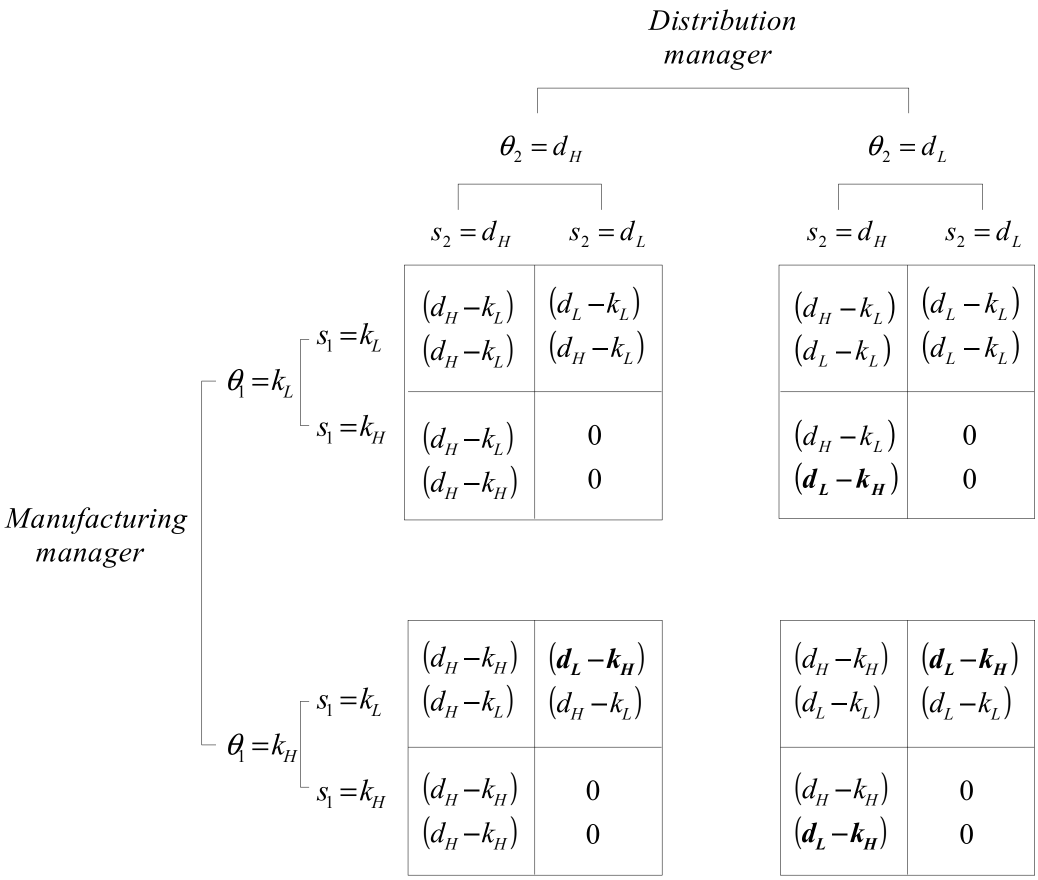

Figure 1: Standard form representation of the dual transfer pricing game

The choices of the manufacturing and distribution managers are indicated by connecting lines, one for each agent. The manufacturing manager selects from rows, the distribution manager from columns within the type-corresponding bimatrix.

We focus our analysis on divisional profits directly as the agents' payoffs are monotonic transformations of the divisional profits.[4] The upper (lower) entry in each cell denotes the manufacturing manager's (distribution manager's) divisional profit. When nature has drawn types, the manufacturing manager selects from rows in the upper or lower bimatrix. The same holds for the distribution manager referring to columns. A zero indicates that the principal decides that, based on the reports, the special order is unprofitable and has to be rejected. Negative payoffs are indicated in bold type.

If truthful reports are expected from both agents, no agent wants to deviate from reporting truthfully. It can easily be seen in Figure 1 that, for example, the k_H −type's profit from reporting truthfully is always at least as high as that from reporting untruthfully ($\widetilde{\theta}_1 = k_L$) but in some cases significantly higher. Analogous results can be derived for all other types. Hence both agents' best strategies are to report truthfully. However, if the agents expect that the manufacturing manager always reports $\widetilde{\theta}_1 = k_L$ and the distribution manager always reports $\widetilde{\theta}_2 = d_H$, their expectations match as well, which follows from Proposition 1.

Proposition 1: *Given strictly positive prior probabilities* $\rho(\theta_i)$ *for all* $i \in \{1,2\}$, *if* $k_L < d_L < k_H < d_H$ *exactly two pure strategy Bayes-Nash equilibria exist. Either both agents report truthfully or the agents always report* $\widetilde{\theta}_1 = k_L$, *and* $\widetilde{\theta}_2 = d_H$ *respectively, independently of the prior probability distribution. The truth-telling equilibrium, denoted as* e_1, *is dominant strategy incentive-compatible and strict for all possible* $\rho_i\left(\theta_{-i} \middle| \widetilde{\theta}_{-i}\right)$ $\forall i \neq -i \in \{1,2\}$, *whereas the other one,* e_2, *is not.*[5]

Proof: At first, we prove that e_1 is an equilibrium. Since the agents' utility payoffs are monotonous in the divisions' profits, we can directly focus on divisions' profits. Assuming that type $\theta_1 = k_L$ can benefit by deviating to $\tilde{\theta}_1 = k_H$, yields:

$$\rho_1(d_H|d_H)(d_H - k_L) > \rho_1(d_H|d_H)(d_H - k_L) + \rho_1(d_L|d_L)(d_L - k_L)$$

$$\Leftrightarrow \quad d_L < k_L$$

which is a contradiction.[6] Examination of $\theta_1 = k_H$ leads to:

$$\rho_1(d_H|d_H)(d_H - k_H) + \rho_1(d_L|k_H)(d_L - k_H) > \rho_1(d_H|k_H)(d_H - k_H)$$

$$\Leftrightarrow \quad d_L > k_H$$

if the k_H-type manufacturing manager could do better by deviating to k_L, which is also a contradiction.[7] In a similar way the same results can be derived with strict inequality for the distribution manager's types $\theta_2 = d_H$ and $\theta_2 = d_L$.

It can easily be seen by comparison of the possible outcomes in Figure 1 that for the same profile and for all *i*, θ_i, $\tilde{\theta}_i$ and $\tilde{\theta}_{-i}$:

$$u_i\left(\tilde{\theta}^*_{-i}, \theta_i \middle| \theta_i\right) \geq u_i\left(\tilde{\theta}^*_{-i}, \tilde{\theta}_i \middle| \theta_i\right) \tag{2}$$

with $\tilde{\theta}^*_{-i}$ as agent's $-i$ equilibrium strategy. Thus, dual transfer prices are Bayesian and dominant strategy incentive-compatible.

The second equilibrium profile, e_2, with the cheating types $\theta_1 = k_H$ and $\theta_2 = d_L$ provides incentives, which always satisfy condition (1) with equality. Assuming that $\theta_1 = k_H$ benefits by deviating from $\tilde{\theta}_1 = k_L$ to $\tilde{\theta}_1 = k_H$, then:

$$\rho_1(d_H|d_H)(d_H - k_H) + \rho_1(d_H|d_L)(d_H - k_H) > \rho_1(d_H|d_H)(d_H - k_H) + \rho_1(d_H|d_L)(d_H - k_H)$$

which is not true. The same result follows for all other types. In contrast to e_1, e_2 does not contain dominant strategies since:

$$u_1(d_L, k_L|k_H) = (d_L - k_H) < 0 = u_1(d_L, k_H|k_H)$$

which violates condition (2). *QED*

Consequently, both truth-telling and cheating are equilibria under individually rational behavior if binding agreements are excluded. Moreover, as an equilibrium with cheating behavior on the parts of the managers does exist under these conditions, the behavior is optimal in a non-cooperative setting and side-payments are not necessary.[8] Side-payments would only be necessary if higher net payoffs were possible for a coalition that cannot be generated by individually rational behavior, whereas at least some member is worse off. However, no agent is worse off individually by playing e_2 strategies, as payoffs are Pareto-efficient.

4. Equilibrium selection

We present an approach to the problem of multiple equilibria in this dual transfer pricing model supported by equilibrium selection theory. The types of interest are $\theta_1 = k_H$ and $\theta_2 = d_L$ since their reports differ in the equilibria. For types $\theta_1 = k_L$ and $\theta_2 = d_H$ the selection problem is trivial since actions are the same in both equilibria. $\theta_1 = k_L$ always reports $\tilde{\theta}_1 = k_L$ and $\theta_2 = d_H$ always reports $\tilde{\theta}_2 = d_H$. Therefore, we focus on the two remaining types since their payoffs differ in a fashion as shown in Table 1.

The table shows the difference in divisional profits of equilibrium e_2 as compared to divisional profits from truth-telling for each constellation of agents' types. The first entry of a triple in each cell represents the increase in the manufacturing manager's divisional profit, the second denotes the increase in the distribution manager's divisional profit. The third entry is the joint probability of the respective combination of agent types.

		Distribution manager's type	
		d_H	d_L
Manu-facturing man-ager's type	k_L	$(0;0;F(k_L,d_H))$	$(d_H-d_L;0;F(k_L,d_L))$
	k_H	$(0;k_H-k_L;F(k_H,d_H))$	$(d_H-k_H;d_L-k_L;F(k_H,d_L))$

Table1: Payoff difference between cheating and truth-telling

Since, for both agents, payoffs from equilibrium e_2 are always at least as high as from equilibrium e_1, e_2 is Pareto-efficient. However, as e_1 is an equilibrium in dominant strategies, collusion cannot occur without communication before reporting in order to agree on 'cheating'. Furthermore, each agent must be sure that the other one will keep his promise. Agents could only expect that e_2 is the equilibrium if it is common knowledge that both agents believe e_2 is the solution. Proposition 2 tells us that this cannot be the case if managers have the slightest doubt regarding the achievement of e_2.

Proposition 2: *Let* $\mu_i(\theta_{-i})\in[0,1]$ *for all* $i\in\{0,1\}$ *be the conjecture of either* $\theta_1=k_H$ *or* $\theta_2=d_L$ *that the opponent plays equilibrium strategy* e_2. *Then,* e_1 *strongly risk-dominates* e_2, *and agents prefer to play truthfully whenever agreeing to cheat is not certain.*[9]

Proof: For $\mu_i(\theta_{-i})\in[0,1]$, assuming e_2 is the solution, the manufacturing manager's incentive yields:

$$\rho_1(d_H)(d_H-k_H)+\rho_1(d_L)\,[(d_H-k_H)\mu_1(d_L)+(d_L-k_H)(1-\mu_1(d_L))]$$

$$> \quad \rho_1(d_H)(d_H - k_H) + \rho_1(d_L)(d_H - k_H)\mu_1(d_L)$$

$$\Leftrightarrow d_L > k_H$$

which is a contradiction.

Analogously, the distribution manager's incentive for preferring e_2 is represented by:

$$\rho_2(k_L)(d_L - k_L) + \rho_2(k_H)\left[(d_L - k_L)\mu_2(k_H) + (d_L - k_H)(1 - \mu_2(k_H))\right]$$

$$> \quad \rho_2(k_L)(d_L - k_L) + \rho_2(k_H)(d_L - k_L)\mu_2(k_H)$$

$$\Leftrightarrow d_L > k_H$$

which is also a contradiction. Thus both agents expect that e_1 is the solution for all sensible conjectures they could make, except if $\mu_i(\theta_{-i}) = 1$ for all $i \in \{0,1\}$. Then the managers are independently indifferent. *QED*

Proposition 2 shows that both managers expect that e_1 is the solution, if there is the slightest doubt about the opponent's action. They are always worse off by playing e_2 strategies, unless they are mutually certain that e_2 is the solution. In the latter case the expectation probability of the commencement of e_2 must be at least 1 for both agents. Therefore, only if both managers could, perhaps due to some exogenous mechanism, entirely trust each other, the solution would be susceptible to collusion where the agents play the cheating equilibrium. However, it is questionable why agents, while cheating the principal, should trust each other without the slightest doubt.

Put differently, both managers can, at best, achieve the same expected payoff by playing e_2 – strategies as with truth-telling, if attaching at least a probability of 1 to the opponent playing his e_2 – strategy. In the presence of any uncertainty about keeping the agreement, a probability of 1 cannot be applied to collusion, and therefore cheating has no chance of coming true. Even if agents agree to cooperate on $e_2 -$strategies before playing the game, the individual rationale of both managers is to choose $e_1 -$strategies, since it keeps any option on gains whilst deterioration from the threat-point (i.e. the payoff the agents receive in the truth-telling equilibrium) is impossible.

In addition, dual transfer prices are shown to be dominant strategy incentive-compatible. This fact has a great advantage for all participants of the game since it is very robust, even if agents have incorrect or perhaps contradictory beliefs. Therefore, the mechanism designer does not need to be aware of the right probability distribution, which is a challenging assumption underlying Bayes-Nash. It is often argued that dual transfer prices would not generate a non-collusive outcome in practice because irrationality or failure to understand the consequences of this behavior might affect the managers' actions. However, findings in experimental game theory do also provide evidence in support of equilibrium e_1. If people are confronted with risk, they tend to react more sensitively to risks of losses as compared to chances of gains, in particular in situations where irrationalities may play a prominent role.[10] On the other hand, there are empirical indications that people cooperate in the repeated prisoner's dilemma; although, from a theoretical viewpoint, cooperation is irrational.[11]

It is straightforward that the reasoning for breaking an agreement is also valid for side-payments, if this were to be a component of an agreement. In contrast to Wagenhofer (1994), neither a $k_H -$type nor a $d_L -$type would keep the promise and it is not individually rational to pay, if the promised behavior of the recipient cannot be enforced. If the promised behavior of the side-payment's intended recipient has already been performed nevertheless, it is not individually rational to make this payment since the recipient cannot enforce the payment. This clearly disproves Wagenhofer's results.

5. Agents' incentives under related scenarios

Given $k_L < k_H$ and $d_L < d_H$ and strict relations between all parameters, there are the following six conceivable type-constellations.

No.	*Type constellation*
1	$k_L < d_L < k_H < d_H$
2	$k_L < k_H < d_L < d_H$
3	$d_L < d_H < k_L < k_H$
4	$d_L < k_L < d_H < k_H$
5	$d_L < k_L < k_H < d_H$
6	$k_L < d_L < d_H < k_H$

Table 2: Type constellations

The main results for dual transfer prices in these scenarios are as follows: in scenarios 2 and 3, the principal does not need reports from the agents for decisions concerning the special order. In scenario 2 (3), the principal can always accept (reject) the special order, independently of the agents' reports, since the order is always profitable (unprofitable). Although truth-telling is only one of several Bayes-Nash equilibria, dual transfer prices trivially implement efficient decisions about the special order in these scenarios. In scenario 2, the distribution manager's (manufacturing manager's) division profit from the special order is positive, regardless of her own type and of the other manager's report. Even for the most unfavorable type-constellation (k_H, d_L) the division profits are always positive for both divisions. Since the special order will always be accepted in scenario 2 for all report combinations, truth-telling is not necessary to implement efficient decisions.[12] Analogously, in scenario 3, with dual transfer pricing, it is impossible that both managers generate a positive profit from the special order, since in this case even the high profit margin is smaller than the low cost parameter. Therefore the special order will always be rejected.

The only profitable type-combination in scenario 4 is (k_L, d_H).[13] There are two Bayes-Nash equilibria: 1) truth-telling and 2) $\tilde{\theta}_1 = k_H; \tilde{\theta}_2 = d_L$. Truth-telling is a dominant strategy for both managers but, more importantly, truth-telling is Pareto-efficient. With the second equilibrium the special order is always rejected because, based on the reports, it is not profitable. Consequently, the managers always generate a division profit of zero. With truth-telling, the special order is accepted for the profitable type-combination (k_L, d_H). In this case, the managers generate positive division profits. If managers play equilibrium 2) strategies, their division profits are definitely zero. If they play the truth-telling equilibrium, they have a chance to generate positive profits. Thus truth-telling is also the risk-dominant Bayes-Nash equilibrium in this scenario. Therefore, dual transfer prices implement efficient decisions concerning the special order.

In scenario 5, if $\tilde{\theta}_2 = d_H$ $(\tilde{\theta}_2 = d_L)$, the special order is profitable (unprofitable), regardless of the manufacturing manager's cost parameter. With a dual transfer price mechanism, truth-telling is the strictly dominant strategy for the distribution manager. Moreover, the order will always be accepted (rejected) if $\tilde{\theta}_2 = d_H$ $(\tilde{\theta}_2 = d_L)$, regardless of the manufacturing manager's report, since the profit, based on the reports, is always strictly positive (negative). The manufacturing manager is indifferent about her own reporting strategies, since her report influences neither the decision concerning the special order nor her own divisional profit. This is sufficient for implementing efficient decisions, even if the production manager chooses to "cheat".

Scenario 6 yields analogous results due to symmetry. Truth-telling is the strictly dominant strategy for the manufacturing manager, but not for the distribution manager. The efficiency of decisions about the special order depends only on the manufacturing manager's report, since the order will always be accepted (rejected) if $\tilde{\theta}_1 = k_L$ $\left(\tilde{\theta}_1 = k_H\right)$, regardless of the distribution manager's report, because the profit, based on the reports, is always strictly positive (negative). Consequently, the implementation of dual transfer prices results in efficient decisions within any possible binary scenario.

6. Modified pricing mechanism

It is often argued that the dual transfer pricing mechanism is not robust against collusion in practice and this hypothesis has been verified experimentally by Dejong *et al*. (1989). The result is attributed to the existence of multiple Bayes-Nash equilibria. Results from other experiments show that it is possible to overcome the trend towards collusion among the agents by modifying the theory slightly. Avila and Ronen (1999) introduced a penalty factor in a repeated game that comes into operation following the agents' moves. The apposition of such a penalty factor eliminates multiple equilibria, but requires that the headquarters, responsible for coordinating charges and credits to the divisions, is aware of the true costs and revenues. It is argued by Avila and Ronen that the realized profits of the divisions will be revealed *ex post* by the accounting reports. However it must be expected that managers have opportunities to conceal the true information even in the accounting.

Therefore, it seems to be useful to modify the pricing rule in order to overcome the trend towards collusion and cheating given that the agents' true parameters are unknown. To this end we change the pricing rule introduced in section 2 of this article in the following way: each manager will be charged/credited an amount depending primarily on the parameter that is reported and secondarily on that which is played by the other manager. Let $\theta_i \in \{\underline{\theta}_i, \overline{\theta}_i\}$ for $i \in \{1,2\}$, then we define the agents' payoff functions as follows:

$$u_1\left(\widetilde{\theta}_2, \widetilde{\theta}_1 \middle| \theta_1\right) = s_P\left[t\left(\widetilde{\theta}_1\right) - \theta_1\right] \tag{3a}$$

$$u_2\left(\widetilde{\theta}_2, \widetilde{\theta}_1 \middle| \theta_2\right) = s_P\left[\theta_2 - t\left(\widetilde{\theta}_2\right)\right] \tag{3b}$$

Define $t\left(\widetilde{\theta}_1\right) = \overline{\theta}_1 - a$ (with $a = \varepsilon$ if $\widetilde{\theta}_1 = \underline{\theta}_1$ and if $\widetilde{\theta}_1 = \overline{\theta}_1$ and $\widetilde{\theta}_2 = \overline{\theta}_2$, and $a = 0$ if $\widetilde{\theta}_1 = \overline{\theta}_1$ and $\widetilde{\theta}_2 = \underline{\theta}_2$), and $t\left(\widetilde{\theta}_2\right) = \underline{\theta}_2 + a$ (with $a = \varepsilon$, if $\widetilde{\theta}_2 = \overline{\theta}_2$ and if $\widetilde{\theta}_2 = \underline{\theta}_2$ and $\widetilde{\theta}_1 = \underline{\theta}_1$, and $a = 0$, if $\widetilde{\theta}_2 = \underline{\theta}_2$ and $\widetilde{\theta}_1 = \overline{\theta}_1$). ε should be a small number.

With the modification of this dual transfer pricing rule, the agents always prefer to play truthfully as truth-telling is the only equilibrium provided by this scheme. We can see this in the proof of Proposition 3.

Proposition 3: *Let* $\theta_i \in \{\underline{\theta}_i, \overline{\theta}_i\}$, *with* $i \in \{1,2\}$, $u_1\left(\widetilde{\theta}_2, \widetilde{\theta}_1 \middle| \theta_1\right) = s_P\left[t\left(\widetilde{\theta}_1\right) - \theta_1\right]$ *and* $u_2\left(\widetilde{\theta}_2, \widetilde{\theta}_1 \middle| \theta_2\right) = s_P\left[\theta_2 - t\left(\widetilde{\theta}_2\right)\right]$ *denote the managers' utility payoffs, given* $\overline{\theta}_1 - \underline{\theta}_1 - \varepsilon > 0$ *and* $\overline{\theta}_2 - \underline{\theta}_2 - \varepsilon > 0$*, then the dual transfer pricing scheme implements truthful reporting.*

Proof: As the game is symmetrical, it is sufficient to focus only on the distribution manager's strategies. Suppose the agents choose to report truthfully. Then, a deviation should provide the following incentive:

$$u_2\left(\widetilde{\theta}_1, \theta_2 \middle| \theta_2\right) < u_2\left(\widetilde{\theta}_1, \widetilde{\theta}_2 \middle| \theta_2\right) \tag{4}$$

This requires that:

$$\frac{\partial u_2}{\partial \tilde{\theta}_2} = \frac{\partial s_P}{\partial \tilde{\theta}_2}\left[\theta_2 - t\left(\tilde{\theta}_2\right)\right] - s_P \frac{\partial t}{\partial \tilde{\theta}_2} > 0 \qquad (5)$$

If $\theta_2 = \underline{\theta}_2$, it is straightforward that (5) is always negative, whatever the other agent reports. If $\theta_2 = \overline{\theta}_2$, (5) is negative for $\tilde{\theta}_1 = \overline{\theta}_1$ and zero for $\tilde{\theta}_1 = \underline{\theta}_1$. To see this, observe that $\partial t / \partial \tilde{\theta}_2 = 0$ and $\partial s_P / \partial \tilde{\theta}_2 = 0$ if the agent switches from $\tilde{\theta}_2 = \overline{\theta}_2$ to $\tilde{\theta}_2 = \underline{\theta}_2$. Thus (5) is a contradiction and the only equilibrium is to report truthfully. *QED*

Proposition 3 tells us that it is possible to implement a dual transfer pricing rule that is not vulnerable to collusive agreements among the agents. In our scheme, the amount the distribution manager is charged, depends stronger on her own report than on the other manager's report and is related to the lowest specification of the profit margin, d_L. She would be charged $d_L + \varepsilon$ every time she reports d_H and also if she reports d_L and the other manager announces k_L.

Recalling our results derived from the traditional dual transfer pricing scheme, we can see that the former cheating types k_H and d_L have strict incentives to play truthfully now, since they would be punished by the mechanism with negative payoffs amounting to $-\varepsilon$ if reporting untruthfully. On the other hand, $k_L -$ and $d_H -$agents run the risk of ending up with zero payoffs if reporting untruthfully, since their deal may be in danger of being rejected by the principal. Truthful reporting provides them a certain positive payoff amounting to $k_H - k_L - \varepsilon$, $d_H - d_L - \varepsilon$ respectively. A spin-off of this scheme is that the agents prefer to have low costs and a high profit margin, prior to the actual game. The reason is that the types k_H and d_L run the risk of being punished even if they tell the truth, since their payoffs in equilibrium may be negative, i.e. $k_H - k_H - \varepsilon$, $d_L - d_L - \varepsilon$ respectively. This may incite the agents to make an effort.

The flaw in this scheme is that it is impossible to rule out cheating equilibria in the continuous case of types, unless managers can be deterred from misreporting values in the accounting.[14] However, this problem can be circumvented in our model as the managers' pay-offs are based on their entries in the accounting that takes place in the last stage. Apparently, they only receive the "award" from cheating if they book the true values. Otherwise they would have to pay the difference between the booked values (e.g. d_H) and the values that have been realized in their divisions (e.g. d_L) out of their own pocket. To see this, note that if the distribution manager essentially earns d_L from the market she has to account for d_H cash on hand to the principal. The inverse logic applies for the manufacturing manager. This discourages the managers from accounting untrue values. The logic here is particularly inverse to the one operating in the model of Ronen and McKinney (1970, 1992). In the latter model it is beneficial for the manufacturing manager to exaggerate her marginal costs and for the sales manager to understate her marginal revenues as the managers are in the position to pouch the difference to the true values in their own pocket without being forced to reveal the true values in the accounting. Therefore the pricing mechanism presented here would be worth examining in an experimental design to prove that the results can be confirmed empirically.

7. Conclusions

We studied the special case of accepting or rejecting a special order with two vertically related divisions in a dual transfer pricing model with two-sided incomplete information. The scenario with discrete distribution of parameters leads to the existence of two equilibria; in contrast multiple equilibria exist in the continuous case. Dual transfer prices implement efficient decisions in both scenarios due to strong risk-dominance of truthful reporting strategies since the agents cannot be absolutely sure that the other agent will keep his promise to play untruthfully in a non-cooperative individually rational setting. On the other hand, agents always behave cooperatively if cooperation is binding. However, then side-payments are not necessary since cheating is, from the managers' perspective, Pareto-efficient even without side-payments. In the absence of the possibility to make binding agreements, collusion is not individually rational.

The main results are also proven in all conceivable discrete scenarios. The equilibrium is only susceptible to collusion if managers are absolutely sure that the opponent will keep his promise, which could be accomplished due to some exogenous enforcement, for example. It has been shown in experimental investigations that agents tend to collude nevertheless. This can be influenced through differences in modeling design and test arrangements.

A crucial issue of this model is that our remuneration rule, which is based on the managers' accounting entries, has a disciplining effect on the managers' report decisions. As the managers only receive their payoffs resulting from cheating if they account for the true specifications of their own parameters at the end of the game, cheating is not an appealing option. The agents would receive a kind of reward for cheating from the principal, who is informed about the cheating at the time when remuneration is paid off. On the other hand, if the agents accounted the untrue values, they had to pay the difference between the booked values (e.g. k_L) and the values that are essentially realized in their divisions (e.g. k_H) out of their own pocket. This discourages the managers from accounting untrue values. The logic here is inverse to the one operating in the model of Ronen and McKinney (1970, 1992). In the Ronen/McKinney model it is beneficial for the manufacturing manager to exaggerate his marginal costs and for the sales manager to understate his marginal revenues as the managers are in a position to pouch the difference to the true values in their own pocket without being forced to reveal the true values in the accounting.

Finally, our results are not in agreement with Wagenhofer (1994), who concludes that the dual transfer pricing rule is unable to induce efficient decisions among the agents. Truthful reporting could only be induced if collusion among the agents can be prevented and collusion would necessarily be accompanied by side-payments. We showed that both truth-telling *and* cheating are Bayes-Nash equilibria. They emerge exactly because of individually rational behavior, without the exogenously assumed ability to make binding promises. However, collusion will not happen as long as the managers cannot be sure that collusion is certain. On the other hand, if managers are able to make binding promises, it does not suffice for the principal to rule out side-payments, since cheating is Pareto-efficient for both agents even without any side-payments.

We have also introduced a modification of the traditional dual transfer pricing mechanism similar to the inclusion of the penalty factor in the Ronen/McKinney model in order to overcome the problem of multiple equilibria by debiting/charging the agents the highest/lowest specification of their own parameters and making the principal's decision of accepting or rejecting the special order contingent on both agents' strategies. This rule is also incentive-compatible and provides first-best behavior in our model.

Notes

1 We use gender-specific attributes alternately.

2 For later computation we assume that any possible combination of reported types can also be interpreted as Arabic numbers starting with 1 for the smallest difference of these combinations, i.e. $d_L - k_H$.

3 Notice that the divisions' profits may be zero if, based on the reports, the order were to be rejected. Therefore the payoffs also depend on the managers' own strategies.

4 However, we have to keep in mind that the displayed values in the payoff matrix will not be paid to the managers but instead a smaller fraction consisting of $\beta\pi_i$, with $\beta < 0.5$.

5 An equilibrium will be denoted as strict if, given the play of the opponent, each player has a unique best reply (Fudenberg and Tirole, 1991: 13).

6 Since we only permit strictly positive $\rho(\theta_i)$, border solutions of $E_i(\cdot)$ are not possible.

7 Notice that the k_L-type manufacturing manager earns nothing from reporting untruthfully, if he comes across a d_L-type distribution manager since, based on the reports, the special order would be regarded as unprofitable and therefore be rejected by the principal.

8 In Wagenhofer (1994) it is wrongly concluded that side-payments would necessarily accompany collusion and that collusion could therefore only be prevented if side-payments can be ruled out.

9 The concept of risk dominance is due to Harsanyi and Selten (1988).

10 For experimental studies and analyses on this issue see Tversky and Kahneman (1986) and Cachon and Camerer (1996).

11 Cf., e.g., Axelrod (1981) and Smale (1980).

12 Without truthful reports, the principal knows that the special order is profitable, but not how profitable it is.

13 This type-constellation is used in Christensen and Demski (1998).

14 There is a differentiability and a jump-discontinuity problem in the case where the special order turns out to be profitable and is therefore being accepted by the principal. Function s_P is not differentiable. We ignore this problem by measuring the change of the absolute value of s_P according to the difference quotient $\Delta s_P / \Delta \tilde{\theta}_i$ and maintaining the form $\partial s_P / \partial \tilde{\theta}_i$.

15 Control mechanisms accomplished by internal audit divisions may prevent some forgery of accounting reports and balance sheets (Financial Services Authority, 2002) but financial crime is still a major problem today and there is some evidence that this problem is persistently under-managed (Basel Committee on Banking Supervision, 2003).

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