Symbiotic production: The case of telecommunication pricing*

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Abstract

In this paper we analyze a generalization of vertical monopolies in which monopoly suppliers trade essential inputs with one another. The most obvious applications of the model, which we call symbiotic production, are to postal and telecommunications services. We show how producers can use per-unit tariffs to achieve cooperative outcomes without colluding directly over consumer prices. We then show the firms have an incentive to collude in the setting of tariffs but that such *collusion will lower consumer prices*. This assumes that the suppliers are otherwise unfettered. In contrast, if the constituent monopolies are regulated, we show that collusion enables the firms to completely undo the restraints of regulation. The model has important policy implications for the international telecommunications market.

KEYWORDS: telecommunications; network pricing; regulation

Recently, the British newspaper, the *Financial Times* claimed to have uncovered arrangements among the world's telephone companies to keep international telephone call charges artificially high. These arrangements, based on obscure accounting practices, were said to be costing consumers $US10 billion per annum worldwide.[1]

The "obscure accounting practices" arise from the way in which international telephone callers are charged. An international call utilizes the services of a

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[1]The stakes are immense. Aronson and Cowley (1988, p7) cite a U.S. Department of Commerce report which estimates total world market for telecommunications in 1990 as $US444 billion which is approximately equal to the GNP of Canada. International telephone calls are the fastest growing component of telecommunications market. We estimate that the international sector may now account for 25 percent of total revenue ($US115 billion per year) which is comparable to the GNP of Austria ($US126 billion).

telephone company at each end. Normally, the revenue for the call is collected by the originating telephone company from the party who initiates the call. The company then compensates the other company for the costs it incurs in handling the call.

There is indeed an international cartel, the CCITT (International Telegraph and Telephone Consultative Committee), whose extensive rules govern the sharing of revenue between telephone companies. "The Recommendations of the CCITT are in effect the real international telecommunications rules of today for, although they are not legally binding, they are nevertheless adhered to by most member nations" (Cullen, 1987). Following their last meeting in November 1988, the CCITT published more than 50 volumes of recommendations relating to telecommunications services, including one volume devoted entirely to comprehensive recommendations regarding the sharing of international call revenues (CCITT, 1988). There, the CCITT recommends three alternative methods of international reimbursement: (1) a flat-rate charge, (2) a per-unit charge or (3) equal division of the revenue. In practice, most countries adopt the per-unit charge "accounting rate" and these are normally set bilaterally at meetings between each pair of countries. In a companion piece (Carter and Wright, 1991), we discuss the CCITT recommendations and devise the optimal tariff structure which involves a combination of the three alternatives.

Telephone services and other forms of telecommunications services, such as telex, telegrams, and data exchange, involve a form of production which has the following characteristics

- Each producer has monopoly power in its own market.
- Each produces both an intermediate and a final good.
- Each producer must purchase the intermediate good from the other producers.

This market form has some parallels with the standard vertical integration model and can be seen as an extension in which the production links extend in both directions. This is illustrated schematically in Figure 1. We call this form *symbiotic production*. Other examples are postal services, the international floral delivery service (Interflora), and the cross-licensing of complementary technologies.

In this paper we analyze a general model of symbiotic production, the most obvious applications of which are to postal and telecommunications services. We show how producers can use per-unit tariffs to achieve cooperative outcomes without colluding directly over consumer prices. We then show the firms have an incentive to collude in the setting of tariffs but that such collusion will lower consumer prices. This is analogous to a standard result in industrial organization that vertical integration of a sequence of monopolies improves welfare (Tirole, 1988, p175). However, the extension to symbiotic production is not

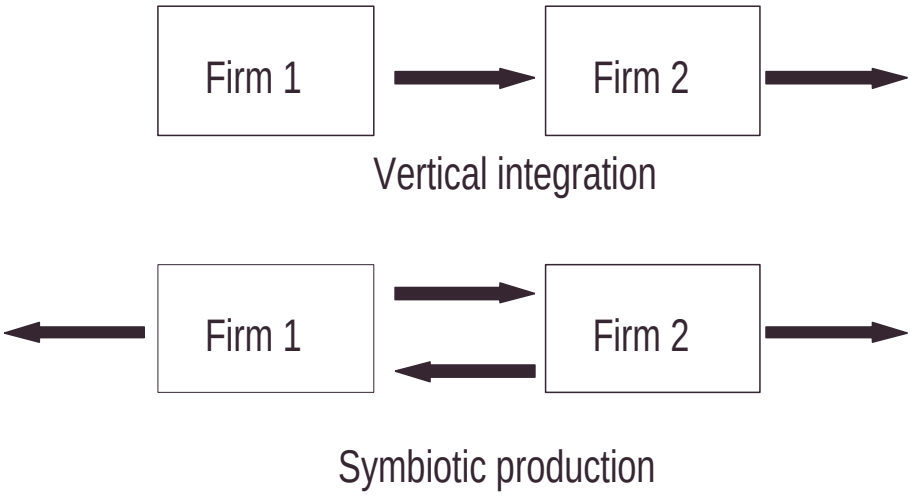

Figure 1: Comparing vertical integration and symbiotic production.

immediate and we have allowed for complementarities to exist between the two monopolists. Furthermore, the results are not identical with those arising from vertical production. Symbiotic production allows each constituent firm have its own individual tariff. The firms can use simple per-unit tariffs to achieve *both* maximum joint profits and an acceptable division of profits. In comparison, vertically related firms require a more complicated tariff, such as a two-part tariff, to get an appropriate distribution of profits. This is important in practice, since the per-unit tariffs avoid the drawbacks of more complicated regimes. Finally, if the constituent monopolies are regulated, collusion enables the firms to completely undo the restraints of profit regulation.

Our results have important implications for international telecommunications markets. Contrary to allegations of the *Financial Times*, collusion over tariff setting may lower (rather than raise) consumer prices and enhance welfare. The telecommunications cartel, the CCITT, may be good for consumers. Overcharging of international telephone calls arises from the local or national monopolization of supply and the CCITT helps to ameliorate the effects of these multiple monopolies. Efficiency in telecommunications will be enhanced by promotion of competition amongst providers nationally, while attempts to

undermine the collusive activities of the CCITT, in the absence of competition amongst local suppliers, will only serve to produce greater inefficiency. On the other hand, given the continued existence of the CCITT and its revenue sharing system, attempts to improve national outcomes through regulation should be viewed with caution, since regulation may be offset through international transactions.

The paper is organized as follows. In Section 1, we set up the model and specify the assumptions. In Section 2, we characterize the profit opportunities available to the firms and derive our two fundamental propositions. Section 3 considers the impact of collusion on consumer prices and welfare while Section 4 deals with regulation. Conclusions are presented in Section 5.

1 The model

We will assume that there are only two firms which sell each other intermediate products.[2] The firms profit functions are:

$$\Pi_1 = p_1 q_1(p_1) - C_1(q_1, d_1) + T_1(d_1) - T_2(d_2)$$
$$\Pi_2 = p_2 q_2(p_2) - C_2(q_2, d_2) - T_1(d_1) + T_2(d_2)$$

We use q_i and d_i to denote the demand for the final good and the intermediate good respectively produced by firm i while $C_i(q_i, d_i)$ denotes the costs incurred. T_i denotes the revenue received by firm i for sales of the intermediate product to firm j. Each firms profit comprises revenue from final sales minus costs plus the net inter company transfer.

It is clear that, by appropriate choice of the transfer functions T_i, firms can achieve any division of the potential joint profit. In practice, for example in the international telecommunications market, firms restrict themselves to linear tariffs, that is a fixed price per unit of intermediate good with no lump-sum transfer. In our companion paper (Carter and Wright, 1991), we discuss the rationale for this restriction. In this paper, we assume this restriction and explore its ramifications. Hence we assume:

A 1 *Tariffs are restricted to be linear, that is*

$$T_i = t_i d_i \qquad i = 1, 2$$

where t_i is the transfer price charged by firm i to firm j.

[2]This restriction is of limited practical significance, since tariffs in telecommunications are typically set bilaterally. Furthermore, the extension of all our results to n firms is immediate, provided that the demand and cost functions are independent, that is firm i's demand is independent of the price charged by firm j and the cost functions are separable. This extension is contained in a detailed appendix, which is available on request from the authors.

The following fixed proportions technology is motivated by the principal application of the paper, namely international telecommunications and postal services.

A 2 *Firm j's demand for firm i's intermediate good depends only on firm j's desired output of its own good, that is*

$$d_i = q_j \qquad i, j = 1, 2, i \neq j$$

We also assume

A 3 *The demand functions q_i and cost functions C_i are twice continuously differentiable with bounded derivatives.*

Given these assumptions, the firms profit functions can be written as

$$\Pi_1(p_1, t_1, t_2) = p_1 q_1(p_1) - C_1(q_1, q_2) + t_1 q_2 - t_2 q_1$$

$$\Pi_2(p_2, t_1, t_2) = p_2 q_2(p_2) - C_2(q_1, q_2) - t_1 q_2 + t_2 q_1$$

In the absence of collaboration, we assume that the firms choose tariffs and consumer prices sequentially. In other words, the firms play a two stage noncooperative game. In the first stage, firms set tariffs. In the second stage, the firms set consumer prices to maximize individual firm profits taking the tariffs as given. This sequential structure is implicit in the recommendations of the CCITT and reflects the practice in international telecommunications, where tariffs are set in bilateral negotiations. In contrast, final output prices are set unilaterally and are much more readily changed than tariffs.[3]

In the second stage, firms set output prices to maximize profits. The outcome is the standard Nash equilibrium. The equilibrium prices are functions of the tariff level. As tariffs vary, this function traces out a set of possible Nash equilibrium prices. We call this function the *Nash equilibrium price mapping* and denote it $p^*(t)$. In the first stage, the firms set tariff levels assuming that consumer prices will be determined as above, that is according to the Nash equilibrium price mapping. The noncooperative equilibrium tariffs and the corresponding consumer prices constitute the Nash equilibrium of the two stage game.

To avoid the complications of multiple equilibria we assume:

A 4 *The Nash equilibrium price mapping is a function (rather than a correspondence), that is*

$$p_i^*(t) \in \arg\max_{p_i} \Pi_i(p_i, t_1, t_2) \text{ is uniquely defined for all } t = (t_1, t_2)$$

[3]International telephone carriers in the U.S. change call prices frequently. For example, during the weekends of June 1993, MCI offered substantial reductions on international calls to a large number of countries. It is unlikely that these were negotiated with all the network partners.

and there is a unique Nash equilibrium, that is

$$t_i^* \in \arg\max_{t_i} \Pi_i(p_i^*(t), t_i) \text{ is uniquely defined.}$$

The Nash equilibrium of the two stage game is defined by $(p_1^*(t_1^*, t_2^*), p_2^*(t_1^*, t_2^*))$.

A 5 *At the Nash equilibrium,* $\partial q_i/\partial p_i < 0$ *and* $q_i > 0$ *for* $i = 1, 2$.

A 6 *At the Nash equilibrium,* $\partial^2 C_i/\partial q_i \partial d_i \leq 0$ *for* $i = 1, 2$.

A 7 *At the Nash equilibrium,*

$$\frac{\partial^2 \Pi_i}{\partial p_i^2} < 0 \qquad \text{for } i, j = 1, 2$$

$$\frac{\partial^2 \Pi_i}{\partial p_i^2}\frac{\partial^2 \Pi_j}{\partial p_j^2} > \frac{\partial^2 \Pi_i}{\partial p_i \partial p_j}\frac{\partial^2 \Pi_j}{\partial p_i \partial p_j} \qquad i \neq j$$

Assumptions A3, A4 and A7 are standard technical assumptions. Assumption A5 rules out the possibility of corner solutions, which seem empirically unlikely in the applications we envisage. Assumption A6 says that the firm's marginal cost of producing the final good q_i does not increase with the level of production of the intermediate good. This assumption enables us to show that final good prices are weak strategic complements — each firm responds to more aggressive pricing by following suit. Alternatively, we could simply assume that prices are strategic complements, in which case we can relax the assumption that each firm is a monopolist in the local market.[4] This is not likely to be important in the applications we are considering here. An increase in the price of calls form New York to London may lead some regular callers to switch and have the other party initiate the call from London. However, this arbitrage effect is likely to be negligible.

The essence of the model is illustrated in Figure 2, which shows the special case of linear demands and constant marginal costs.[5] Total profit of firm 1 comprises the two shaded areas in Figure 2, being the profit (net of tariff) on the domestic market and the tariff revenue derived on the foreign market. Under the assumptions of the model, prices will be determined where marginal revenue equals marginal cost (including tariff) in each market. Given this pricing behavior, each firm will act so as to maximize the tariff revenue received from the foreign firm, which will be achieved by maximizing the area under the marginal revenue curve of the foreign firm. The firm's objective is to maximize the sum of both areas. The assumption that they make tariff and price decisions sequentially is essentially that they treat these two areas independently. The general model requires more sophisticated analysis, but the basic insight remains. The analysis of the general model is taken up in the next section.

[4] This was done in an earlier version of the paper which is available from the authors on request.

[5] Non-tariff marginal costs are assumed to be zero in drawing Figure 2.

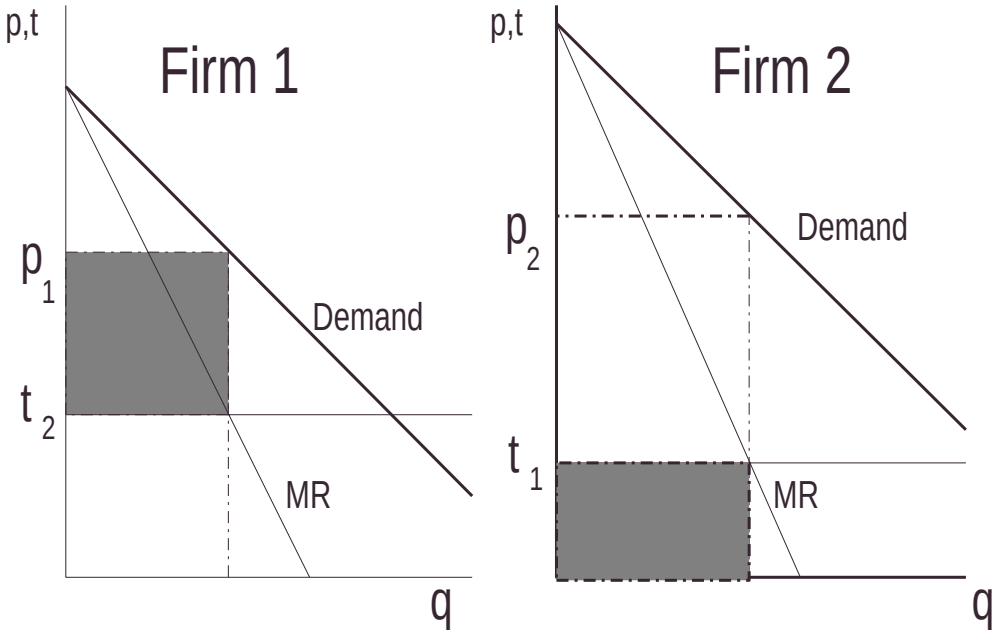

Figure 2: Linear demands, constant marginal costs.

2 Characterization of the profit possibilities

The central results of the paper flow from the following two propositions.

Proposition 1 *Assume (A1) – (A5) and (A7). Any final good prices $\tilde{p}_1$ and $\tilde{p}_2$ which yield non-negative profits to each firm can be obtained by noncooperative pricing behavior by appropriate choices of t_1 and t_2.*

Proof — see Appendix.

Proposition 1 shows that the firms lose nothing by choosing tariffs and prices sequentially. It establishes that the benefits of collusive pricing can be achieved by setting tariffs collusively and then setting prices non-cooperatively according to $p^*(t)$. *The firms can indirectly collude over consumer prices by colluding over transfer prices*. The second proposition shows that the firms have an incentive to collude over transfer prices.

Proposition 2 *Assuming (A1) – (A7), the Nash equilibrium is Pareto inefficient. That is, both firms can be made better off by appropriate choice of tariffs, given that consumer prices are set non-cooperatively.*

Proof — see Appendix.

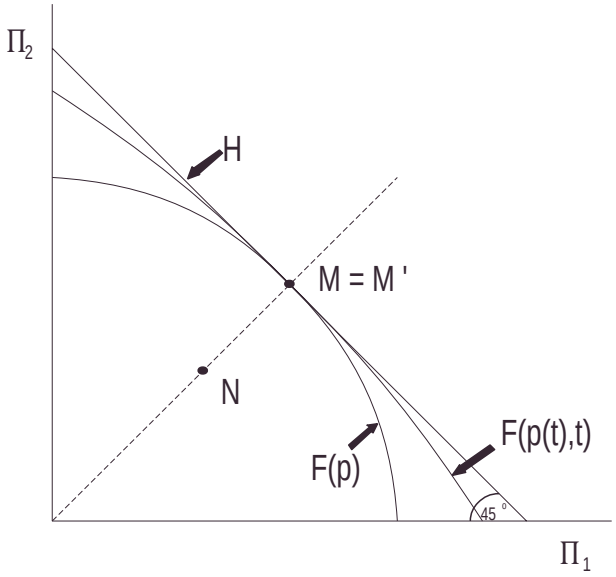

Figure 3: Profit possibilities for symmetric firms.

The intuition for this result is similar to the double marginalization externality in vertically related firms — a reduction in one firm's tariff causes only a second order loss of its own profits but a first order increase in the other firm's profits. The main extension here is that the double marginalization principle continues to hold with symbiotic production and when complementarities exist between firms.

For the general case we illustrate the profit possibilities in Figures 3 and 4. Let $F(p)$ denote the profit possibility frontier where the firms can choose any prices while tariffs are constrained to zero (no inter company transfers). Let $F(p^*(t), t)$ denote the profit possibility frontier where the firms choose any tariffs while prices are chosen noncooperatively given the tariffs. In other words, $F(p^*(t), t)$ is the image of the Nash equilibrium price mapping in profit space. Let M and M' denote the points along $F(p)$ and $F(p^*(t), t)$ respectively at which joint profits are maximized. Finally, let N denote the Nash equilibrium outcome defined in Section 2.

Consider first the special case in which the firms have identical profit functions (Figure 3). By Proposition 1, the firms can choose (linear) tariffs which yield the joint profit-maximizing outcome. Since the firms are identical, these

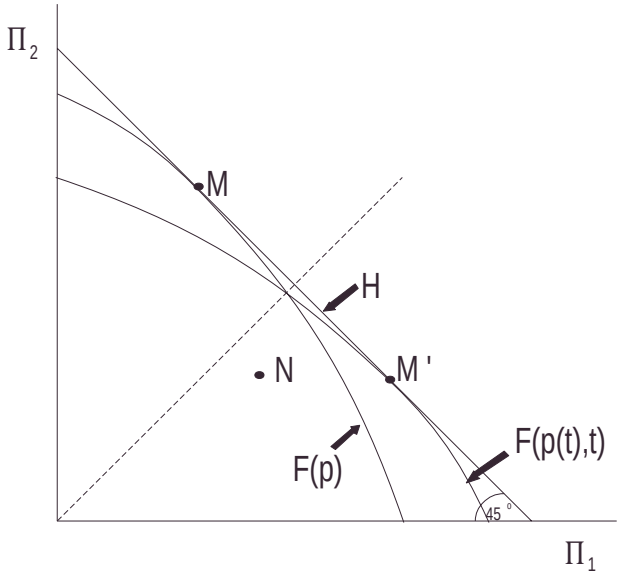

Figure 4: Profit possibilities for asymmetric firms.

tariffs imply no re-distribution of profits compared with point M. Thus points M and M' coincide for identical firms. Proposition 2 implies that N lies in the interior of $F(p^*(t), t)$.

One way of understanding Figures 3 and 4 is as depicting the different constraints imposed by restricting the tariff regimes. The least restrictive regime involving general tariff functions $T_i(d_i)$ generates the linear profit frontier H, since the best the firms can do is to redistribute the joint maximum profit M through lump sum transfers. Restricting the firms to linear tariffs does not constrain the profit opportunities *provided* the firms can price accordingly. The firms can still achieve the joint maximum profit and then mimic lump sum transfers by suitable choice of tariff levels. Linear tariffs do constrain profit opportunities if firms also act independently in setting prices given tariffs $F(p^*(t), t)$. Alternatively, profit opportunities are constrained if tariffs are precluded altogether.

The profit possibility frontiers for non-identical firms are illustrated in Figure 4. By Proposition 1, there exist linear tariffs which imply the joint profit maximizing prices (with independent pricing) and achieve the same total profit, although with a different distribution between the firms. Hence points M and M' must lie on the same hyperplane, though in general they will not coincide.

It follows that the profit possibility frontiers under the two regimes $F(p)$ and $F(p^*(t), t)$ will only partially overlap as shown in Figure 4. While both firms would benefit from a general tariff regime (including lump-sum transfers), their interests in the two alternative restricted regimes are conflicting. Again we note that N lies in the interior of $F(p^*(t), t)$ by Proposition 2.

It is not necessarily the case that M' is Pareto-superior to N. For example, if one firm was very much smaller than the other, it might do better by exploiting the bigger firm's demand at the Nash equilibrium N than cooperating over tariffs at M'. This observation may have relevance for the trading between telephone systems of vastly different sizes.[6]

Figure 3 suggests that, with symmetric conditions, firms will lose nothing by relying on linear tariffs (rather than more general tariff structures) and pricing non-cooperatively provided they cooperate on the tariff levels.[7] Figure 4 suggests that this regime may also be reasonable with asymmetric firms, provided the asymmetries are not excessive. This point illustrates another key difference between vertical integration and symbiotic production. In the former, linear tariffs are inadequate for the dual tasks of maximizing total profits and redistributing profits. In symbiotic production, the use of two transfer prices allows both roles to be achieved with linear tariffs. This is important because it avoids any need to rely on franchise fees or price maintenance, which have serious drawbacks when there is uncertainty or private information (see Tirole, 1988, p176).

The profit possibilities for vertically related firms are depicted in Figure 5, where $F(p(t), t)$ represents the profit possibility frontier where the downstream firm (2's) output price $p(t)$ is conditional on the intermediate price t charged by firm 1. The point N is the optimal linear tariff for firm 1 — the non-cooperative equilibrium. The externality due to double marginalization is represented by the distance between the $F(p(t), t)$ locus and the 45 degree line. This shows the inadequacy of linear tariffs to eliminate the double marginalization externality in vertically related firms.

3 The effect of collusion on prices

In 1990, the Financial Times alleged that, in colluding over tariffs, the world's telephone companies were able to artificially raise consumer prices and extract an additional $US10 billion in revenue worldwide. Our analysis so far suggests that the telephone companies have a powerful incentive to collude since the Nash equilibrium is inefficient. However, contrary to these allegations, our results

[6] We understand that Australia has tried unsuccessfully to persuade small Pacific nations to lower bilateral tariffs. The *Financial Times* notes that some newly industrialized countries, which export many workers to richer economies who then call home, have proved very resistant to negotiating lower tariffs. In a future paper, we plan to explore the specific implications of asymmetry and test these empirically.

[7] Of course if the firms are symmetric, net tariffs will be zero under all regimes.

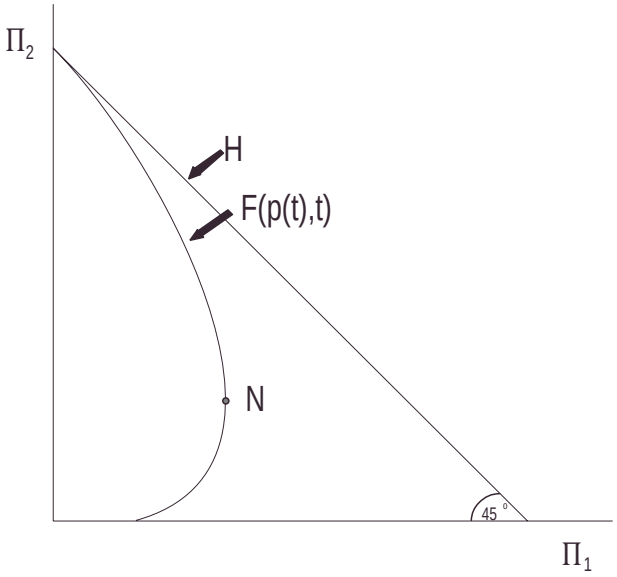

Figure 5: Profit possibilities for vertically integrated firms.

suggest that collusion over tariffs will in fact lower prices and benefit consumers. Starting from the Nash equilibrium N, firms increase their profits by jointly lowering rather than raising tariffs. Assuming that the firms continue to price independently, lower tariffs lead to lower prices and greater benefit to consumers. We formalize this result in the following proposition.

Proposition 3 *Given assumptions (A1) – (A7) and independent pricing behavior, collusion over tariffs will lead to lower prices.*

Proof — see Appendix.

The intuition here is analogous to the elimination of double marginalization through vertical integration (see for example Tirole, 1988, p174-175). In this case the double marginalization effect works both ways and both firms have an incentive to remove it. In other words, the firms impose an externality on each other through tariffs and this externality is reflected in consumer prices. Collusion enables internalization of the externality and a corresponding reduction in costs and consumer prices.

4 The effects of regulation on prices

Proposition 1 showed that firms can effectively collude over prices by colluding over tariffs while setting prices independently. The essence of this result carries over to regulated firms, provided that the regulated prices depend in some way upon tariffs.[8] Suitable examples include marginal cost pricing, average cost pricing and average variable cost pricing. The intuition is straightforward. Proposition 1 characterized attainable prices assuming that they were a given function of tariffs, namely the Nash equilibrium price mapping. The generalization asserts that the proposition holds for any univalent tariff-price relationship.

In order to compare the prices chosen in the regulated and unregulated cases under linear tariffs, we would have to determine the outcome of bargaining in each case. We can abstract from the bargaining problem by assuming identical firms. Thus, in order to illustrate the more general result, we consider the effectiveness of marginal cost pricing in the symmetric case. This yields the following proposition.

Proposition 4 *Assuming (A1) – (A4) and identical firms, marginal cost pricing regulations are completely ineffectual.*

Proof — see Appendix.

The firms can completely undo the effect of cost-based regulations on their output markets by appropriately setting transfer prices on their input markets. Furthermore, the result trivially extends to the case of two-part tariffs even when the firms' profit functions or bargaining powers differ. Finally, it is worth noting that, in the case of two-part tariffs, the result is not restricted to symbiotic production. For example, in the standard vertical relationship, regulations on the downstream firm can be completely negated through the use of an appropriate two-part tariff by the upstream firm.[9] To make regulations effectual would require international cooperation between regulatory authorities, who could bilaterally agree to keep tariffs constrained to marginal cost. They could then enforce marginal cost pricing unilaterally in each country.[10]

While collusion amongst telephone companies appears beneficial for consumers in an unregulated environment, this outcome may be reversed when the firms are regulated. This suggests a need for *international coordination*

[8] If this were not the case, in for example the case of international telecommunications, a decision to regulate in country i could allow country j to extract all the rents through an appropriate linear tariff. This would be the case unless the regulators in the two countries could coordinate their regulations.

[9] Spulber (1989, p.277) notes that regulations can be undermined in a vertically integrated firm.

[10] As countries deregulate their telecommunications industries, regulated firms will fewer regulated partners with which to trade. Their regulated prices will be more exposed to being undone by the other unregulated firms in other countries. This should reduce the payoff to regulation and perhaps hasten the spread of deregulation.

on competition in and regulation of telecommunications. Individual countries regulatory efforts may be undermined by the international cartel.

5 Conclusion

Symbiotic production occurs when two or more firms sell each other essential intermediate goods. Important examples involve international telecommunications and postal services. In the case of two firms, we showed that collusion between the firms may be good for consumers and that price regulation may be ineffective.

6 Appendix [11]

Proof of Proposition 1. (p_1^*, p_2^*) are determined for given (t_1, t_2) by the first order conditions

$$\frac{\partial \Pi_1}{\partial p_1} = 0 \tag{1}$$

$$\frac{\partial \Pi_2}{\partial p_2} = 0 \tag{2}$$

Evaluate (1) and (2) at $(\tilde{p}_1, \tilde{p}_2)$. Then solve for the resulting (t_1, t_2). Denote these $(\tilde{t}_1, \tilde{t}_2)$. (A3) and (A5.1) guarantee the existence of $(\tilde{t}_1, \tilde{t}_2)$ as given. (A4) ensures the solution (p_1^*, p_2^*) to (1) and (2), for those values $(\tilde{t}_1, \tilde{t}_2)$ is equal to $(\tilde{p}_1, \tilde{p}_2)$ as required. □

Proof of Proposition 2. Let $\Pi_i^* = \Pi_i(p_i^*, p_j^*)$. The Nash equilibrium is characterized by the first-order conditions

$$\frac{d\Pi_i^*}{dt_i} \equiv \frac{\partial \Pi_i^*}{\partial p_i}\frac{\partial p_i}{\partial t_i} + \frac{\partial \Pi_i^*}{\partial t_i} + \frac{\partial \Pi_i^*}{\partial p_j}\frac{\partial p_j}{\partial t_i} = 0, \quad i, j = 1, 2, i \neq j \tag{3}$$

Rearranging (3), noting $\partial \Pi_i^*/\partial p_i = 0$ gives

$$\frac{\partial \Pi_i^*}{\partial p_j} = -\frac{\partial \Pi_i^*/\partial t_i}{\partial p_j/\partial t_i} \tag{4}$$

Similarly

$$\frac{d\Pi_i^*}{dt_j} \equiv \frac{\partial \Pi_i^*}{\partial p_i}\frac{\partial p_i}{\partial t_j} + \frac{\partial \Pi_i^*}{\partial t_j} + \frac{\partial \Pi_i^*}{\partial p_j}\frac{\partial p_j}{\partial t_j} \tag{5}$$

[11] This appendix contains abbreviated proofs for the propositions in the paper. A longer appendix containing detailed proofs and extensions of the propositions for n firms is available on request from the authors.

Substituting (4) into (5), noting $\partial\Pi_i^*/\partial p_i = 0$, gives

$$\frac{d\Pi_i^*}{dt_j} = -q_i - q_j \frac{\partial p_j/\partial t_j}{\partial p_j/\partial t_i} \tag{6}$$

Totally differentiating the first-order conditions and using A5, A6 and A7 we get

$$\frac{\partial p_i}{\partial t_i} \geq 0 \qquad i = 1, 2 \text{ and } \frac{\partial p_i}{\partial t_j} > 0 \qquad i, j = 1, 2, i \neq j \tag{7}$$

Note we use A5 and A6 to show $\partial^2\Pi_i^*/\partial p_i \partial p_j \geq 0$ in this step.

At the Nash equilibrium $d\Pi_i^*/dt_i = 0$, $i = 1, 2$. Also from (6), (7) and A5, $\frac{d\Pi_i^*}{dt_j} < 0$, $i, j = 1, 2, i \neq j$. From the Nash equilibrium, a simultaneous reduction in tariffs will increase the profits of both firms. □

Proof of Proposition 3. This follows immediately from Proposition 2 and equation (7). □

Proof of Proposition 4. We have already seen in Section 3 that, in the absence of regulation, identical firms would choose prices which maximised their joint profit. Under marginal cost pricing, the regulated price loci are:

$$p_1^R = \frac{\partial C_1}{\partial q_1} + t_2 \tag{8}$$

$$p_2^R = \frac{\partial C_2}{\partial q_2} + t_1 \tag{9}$$

Since $\partial C_i/\partial q_i$, $i = 1, 2$ is bounded, the firms can achieve any prices by appropriate choice of t_1 and t_2. Identical firms will indeed choose t_1 and t_2 so as to attain the joint profit maximizing outcome. These t_1 and t_2 will then lead under the regulations to the desired prices (provided the tariff-price relationship is univalent). □

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