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Interconnection in Network Industries

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Abstract. Recent deregulation of telecommunications in the U.S. and elsewhere has highlighted the importance of interconnection in network industries. In this paper, we analyse interconnection in a deregulated network where the participants compete in the final retail market. We consider both the case of a mature industry as well as one where a new entrant challenges the incumbent. In the later case, network externalities allow the incumbent to use the terms of interconnection to maintain its dominant position. Moreover, in either case, competition in the retail market can be undermined by collusion over access prices. We discuss the implications for some of the provisions of the new U.S. *Telecommunications Act*, specifically mandatory interconnection and reciprocity of tariffs, comparing these to the simple "bill and keep" rule.

Key words: Deregulation, interconnection, networks, telecommunications.

I. Introduction

Stimulated by technological change and a pervasive deregulatory mood, network industries such as electricity, rail and telecommunications are being transformed all around the world. Previous national monopolies are being privatized and competition encouraged. A characteristic feature of network industries is that competing suppliers need to interconnect, to utilize the facilities of one another to provide services to their final consumers. The determination of interconnection prices is an issue of significant economic importance. Since typically the industries are marked by considerable asymmetry, with an established incumbent facing much smaller entrants, the determination of interconnection fees is crucial for the economic feasibility of entry and the viability of competition.

While interconnection is a feature of all network industries, it is a particular requirement in telecommunications. In many countries (e.g., Australia, United Kingdom), interconnection fees between telecom providers are fixed by an industry specific regulatory authority. In the United States, the recent *Telecommunications Act* provides for interconnection agreements to be negotiated between the parties, subject to the approval of the State regulatory authority. A different course was

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charted in New Zealand. When the national monopoly (Telecom) was privatized in 1990, no specific industry regulator was established. Instead, in the course of wide-ranging deregulation, the government explicity adopted a policy of "light-handed regulation", relying on the enforcement of existing antitrust legislation to preclude anti-competitive practices.[1] Some observers suggest that the New Zealand approach is likely to be followed in other jurisdictions (Laffont et al., 1996), and interconnection problems are likely to assume increasing importance.

Interconnection has long been a feature of international telecommunications, where calls initiated on one national network are completed on another national network, and may well pass through other networks on the way. Typically, callers are charged by their own local network, which then reimburses the other network(s) for completing the call. The modes and rates of reimbursement are determined by bilateral agreements, within framework laid down by the CCITT (International Telegraph and Telephone Consultative Committee). In an earlier paper (Carter and Wright, 1994), we analysed international telephone pricing in a model of symbiotic production, where producers with market power purchase essential inputs from each other. We showed that the participants could effectively collude over retail prices by colluding over wholesale tariffs. Contrary to popular belief, however, independent action led the firms to set tariffs too high. Cooperating firms have an incentive to lower tariffs, which would in turn lead to lower consumer prices and increased welfare.

In international telecommunications, the number of subscribers to each network is determined exogenously (by geography). Local call interconnection differs fundamentally in that the number of subscribers to each network is endogenous. Competition between networks not only affects the volume of calls, it also affects the share of the population which choose to subscribe to the network. In this paper, we adapt our earlier work to model local call interconnection. Our results raise some doubt about the ability of competition to achieve efficient outcomes in network industries. Under appropriate conditions, we find that

- Interconnection fees provide networks with a legitimate instrument of collusion.
- Consequently, competition in the retail market can be undermined by collusion over access charges.
- Moreover, if collusion over access charges is prevented, outcomes are worse for both consumers and producers.
- Where there is some asymmetry of demand between the firms, forcing a common tariff (reciprocity) can be harmful to welfare.

Most of the previous literature on interconnection has presumed a one-way flow of services and a regulated output market (e.g., Baumol and Sidak, 1994). Two recent working papers (Armstrong, 1996; Laffont et al., 1996) have addressed the

[1] Disagreement over interconnection provoked a famous New Zealand antitrust case, *Clear v. Telecom*, which we analyse in Carter and Wright (1997).

same issue as us. However, they mainly deal with symmetric (identical) firms.[2] Our paper differs in that it:

1. Provides general results (Propositions 1 to 4), which do not depend upon particular functional forms or the characteristics of consumers,
2. deals explicitly with asymmetric firms,
3. allows the possibility of no connection, and
4. considers the network effects which may then arise.

Though different network industries have different features, the essence of the interconnection problem is common to all. Our model provides a framework which, with appropriate modifications, can be applied to other network industries, such as electricity, gas, postal services and the internet.[3] Other potential application include code sharing agreements amongst airlines and the reimbursement arrangements between banks for the use of automatic teller machines. Our model offers a general framework for analyzing interconnection disputes between competing networks.

In the next section, we introduce our model of firm behaviour. In Section III, we derive some analytical results for an important benchmark case, where the firms are identical. To explore the behaviour of the model with asymmetric firms requires that we further specify the nature of demand which determines market share. We undertake this in Section IV. In Section V, we combine the specific model of market share with the general model of firm behaviour to explore the implications of various possible interconnection agreements. We deal with both a mature industry (two identical firms offering differentiated products) and a new entrant challenging an incumbent. For the latter, we deal with both the case in which the incumbent has an intrinsic advantage (brand loyalty) and also with the case in which the incumbent initially dominates the market due to network effects. This section concludes with a comparison with a regulated industry. We summarize the policy implications of our analysis in Section VI.

II. Modeling the Firms

To capture the essence of the local telephone interconnection issue, we model a duopoly in which two firms compete for final customers (subscribers). We assume that the total number of customers is fixed. Each customer belongs to just one network, but wishes to make calls to subscribes on the other network. Consequently, each firm must make calls to and receive calls from the rival network. Each network charges the other network an access charge or tariff for completing calls.

[2] In another related paper, Economides, Lopomo and Woroch (1996) obtain results apparently at variance with our conclusions. However, their framework is more similar to our earlier paper (Carter and Wright, 1994) in which market shares are exogeneous, since firms do not take account of the implications for market share in determining their retail prices.

[3] McWha and Wright (1997) deal with electricity networks.

A fundamental assumption in the model is the network interconnection is transparent to the user in the sense that:

- Firms are unable to discriminate between calls, by charging more for calls which are completed on the other network,
- subscribers do not discriminate between networks in choosing who to call.

The decision of which network to join depends *inter alia* upon the retail prices p_i charged by the networks, and consequently the total number of subscribers s_i to network i is a function of both p_1 and p_2.[4] However, once a subscriber has joined a particular network, her individual demand for calls q_i depends only on the price charged by her own network, and not on the price charged by the rival network. That is

$$q_i = q_i(p_i)$$

$$s_i = s_i(p_1, p_2)$$

Since we assume constant marginal costs of calls c_i and constant marginal costs of interconnection d_i, the absolute scale of the network does not matter. For simplicity, we normalize so that the total number of customers is one. Consequently, the number of subscribers s_i on network i is also the market share of firm i.

The average customer of network i makes $q_i(p_i)$ calls per period, yielding revenue of $P_i Q_i(p_i)$. A proportion s_j of these calls are designed for the other network, incurring an interconnection charge of $t_j s_j q_i(p_i)$. Therefore the total net revenue from retail operations for firm i is

$$\text{Retail net revenue} = s_i(p_i - c_i - t_j s_j)q_i(p_i)$$

Similarly, $s_j q_j(p_j)$ calls are initiated on the other network, and a proportion s_i of these are completed on network i. Consequently, a total of $s_i s_j q_j(p_j)$ flow into network i, and therefore interconnection provides wholesale revenue of $t_i(s_i s_j q_j(p_j))$. The total profit of each firm i is the sum of retail and wholesale net revenue, namely

$$\Pi_i(p_1, p_2, t_1, t_2) = s_i \pi_i(p_i) + s_i s_j((t_i - d_i)q_j(p_j) - t_j q_i(p_i))$$

where $s_i + s_j = 1$ and π_i denotes the average (per subscriber) profit of firm i excluding interconnection charges and costs, that is

$$\pi_i(p_i) = (p_i - c_i)q_i(p_i)$$

[4] In this paper, we confine ourselves to simple linear prices and tariffs. We are currently working on another paper which deals explicitly with two-part prices and tariffs. Early results confirm the results in this paper. One justification for studying linear tariffs is that they appear common practice. In New Zealand, Clear and Telecom ultimately agreed upon linear tariffs, although two-part and other pricing schemes were available to them (Carter and Wright, 1997).

Each firm has two strategic variables p_i and t_i. Throughout the paper,

- we assume that retail prices p_i are set noncooperatively given access prices, and
- we explore the consequences of different rules for setting access prices t_i.

We envisage the possibility of collusion over the determination of access charges t_i, while excluding by assumption collusion over retail prices p_i. Our justification for this modeling choice is that antitrust law prohibits collusion over retail prices, while negotiation over interconnection arrangements is permitted and indeed encouraged.

Given access charges t_1 and t_2, each firm chooses its retail price p_i to maximize its own profit. This is a standard duopoly with differentiated products, and we assume the firms play the Bertrand equilibrium. Assuming an interior solution, the equilibrium is characterized by the first order conditions

$$\frac{\partial \Pi_i}{\partial p_i} = 0, \quad i = 1, 2 \tag{1}$$

These conditions implicitly define the equilibrium retail prices p_i as functions of the access prices t_1 and t_2.

Defining

$$X_i = s_i \pi_i(p_i)$$

$$Y_i = s_i s_j q_j(p_j)$$

$$Z_i = s_i s_j q_i(p_i)$$

We can rewrite the profit function as

$$\Pi_i(p_1, p_2, t_1, t_2) = X_i + Y_i(t_i - d_i) - Z_i t_j$$

so that the first order conditions (1) yield the following system of linear equations

$$\frac{\partial \Pi_1}{\partial p_1} = \frac{\partial X_1}{\partial p_1} + \frac{\partial Y_1}{\partial p_1}(t_1 - d_1) - \frac{\partial Z}{\partial p_1} t_2 = 0 \tag{2}$$

$$\frac{\partial \Pi_2}{\partial p_2} = \frac{\partial X_2}{\partial p_2} - \frac{\partial Z_2}{\partial p_2} t_1 + \frac{\partial Y}{\partial p_2}(t_2 - d_2) = 0 \tag{3}$$

Since the system is linear in t_1 and t_2, the optimal prices p_1 and p_2 are uniquely determined by the tariffs provided the system is of full rank, that is

$$\frac{\partial Y_1}{\partial p_1}\frac{\partial Y_2}{\partial p_1} - \frac{\partial Z_1}{\partial p_1}\frac{\partial Z_2}{\partial p_1} \neq 0$$

This implies the important conclusion that access charges can be used as an instrument of collusion. Specifically, although the firms set final customer prices noncooperatively, they can achieve any desired equilibrium prices by appropriate choice of access charges.

One possibility is that the firms also set access prices noncooperatively. This leads to a two stage game. In the first stage, the firms independently set their interconnection charges t_i, taking into account the equilibrium pricing behaviour embodied in (1). In the second stage, the firms set their retail prices and compete for subscribers. The (subgame perfect) Nash equilibrium of the two stage game is determined by the simultaneous solution of

$$\frac{\mathrm{d}\Pi_i}{\mathrm{d}t_i} = \frac{\partial \Pi_i}{\partial p_i}\frac{\mathrm{d}p_i}{\mathrm{d}t_i} + \frac{\partial \Pi}{\partial t_i} + \frac{\partial \Pi_i}{\partial p_j}\frac{\mathrm{d}p_j}{\mathrm{d}t_i} = 0, \quad i = 1, 2 \tag{4}$$

where (4) is evaluated subject to equilibrium price mapping determined by (1).

The preceding discussion implicitly assumed the existence of a pure strategy Bertrand equilibrium in the second stage pricing game. In general, such an equilibrium cannot be guaranteed. When the products of the two firms are highly substitutable, price competition between them may be unstable, with each trying to undercut the other and corner the market. There may be no equilibrium, in which case it is difficult to make any predictions about the likely outcome. In Section IV, we model the determinants of market share, which clarifies the factors determining the existence or otherwise of equilibrium in the pricing game.

Even where existence of equilibrium is ensured, full rank of the system (2) and (3) cannot be guaranteed without further specification of the market share function s. However, full rank can be guaranteed when the firms have identical market shares, so that $s_1 = s_2 = 1/2$. This special case, which provides an insightful illustration of the properties of the model, is discussed in the next section. In the following sections, we explore the behaviour of the model with explicit market share functions. This analysis confirms the predictions of the model in the symmetric case, and provides some insight into the implications of asymmetry.

III. A Special Case: Symmetric Firms

A useful benchmark to consider involves identical firms, that is two firms which face identical demands and have equal costs. In these circumstances, the firms will choose identical prices in equilibrium, and therefore share the market equally.[5] For this special case, we can derive some analytical results.

We assume

5 The assumption of symmetry (Assumption A1) is stronger than necessary to establish the following propositions. We use the fact that symmetry implies equal market shares, which is all that we require. Equality of outcomes could arise even with asymmetric firms. Moreover, equal market shares is a sufficient, not a necessary condition, for the following propositions.

A.1. *The firms are identical, that is*

$$q_1(p) = q_2(p) = q(p)$$

$$c_1 = c_2 = c$$

$$d_1 = d_2 = d$$

and the share functions are symmetric, that is

$$s_1(p_1, p_2) = s_2(p_2, p_1)$$

We also assume

A.2. *The common demand function q is twice continuously differentiable with bounded derivatives.*

A.3. *For every pair of tariffs t_1 and t_2, there exists a unique Bertrand equilibrium characterized by the first-order conditions (1).*

A.4. *At the Nash equilibrium of the two stage game*

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

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

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

Assumptions A2 and A4 are standard technical assumptions. A4 implies that the profit functions are strictly concave at the Nash equilibrium, and also that retail prices are strategic complements. A3, which is crucial to our result, assumes away the possibility of nonexistence referred to above. Therefore the following propositions will only hold where there is limited substitutability in demand between the two networks. The full import of this assumption will be explored in the following section, where we model demand explicitly. Proofs are contained in a supplementary appendix available from the authors on request.

PROPOSITION 1. *Assuming A1 and A3, any common retail price p (which yield nonnegative profits to both firms) can be sustained by noncooperative pricing behavior by appropriate choice of tariffs t_i.*

From an antitrust perspective, this is a disturbing result. In most jurisdictions, collusion over retail prices is illegal and firmly discouraged. However, collusion over access charges is allowed and indeed often encouraged. Our result shows that the firms can effectively collude over retail prices by colluding over tariffs. The networks can use interconnection fees to effectively exploit their joint monopoly power. In particular, a two-firm network can achieve an outcome which maximizes their joint profits, pricing the same as a single monopoly.

COROLLARY 1. *Assuming A1 and A3, prices that maximize joint profits can be supported by the appropriate choice of tariffs.*

If their bargaining strengths differ, the corollary does not mean that otherwise symmetric firms will necessarily agree on the joint profit maximum prices.They may agree on another outcome which favours the stronger firm. However, if they are forced to charge reciprocal (equal) tariffs, their conflict disappears, their interests are aligned and they have mutual interest in agreeing on tariffs which maximize joint profits.

PROPOSITION 2. *If tariffs are required to be reciprocal, a deregulated duopoly will choose tariffs which support monopoly prices and enable the firms to maximize joint profits (assuming A1 and A3).*

Contrary to the standard result, increasing the number of firms will not produce a more competitive outcome. An industry of n firms can use tariffs to collude over final retail prices. In particular, they can collude to achieve the monopoly price.

COROLLARY 2. *Propositions 1 and 2 hold in a network of n firms.*

Furthermore, the ability to use tariffs as an instrument of collusion is not constrained by the imposition of certain types of price regulation. We illustrate this for marginal cost price regulation, showing that the firms can still achieve monopoly profits by the choice of appropriate tariffs.

PROPOSITION 3. *Assuming A1, a two firm network regulated to price at marginal cost will choose tariffs which support monopoly prices and enable the firms to maximize joint profits.*

Suppose, however, that collusion in setting access prices were prohibited, so that firms set their access charges as well as their retail prices noncooperatively. The outcome them is the Nash equilibrium in the two stage game, which is in many respects the worst possible outcome, both for the firms and consumers.

PROPOSITION 4. *Assuming A1–A4,*

1. *Starting from the Nash equilibrium of the two-stage game, both firms can be made better off by reducing tariffs.*

2. *At the Nash equilibrium of the two stage game, retail prices are increasing functions of tariffs. Consequently collusion over tariffs will reduce retail prices and improve consumer welfare.*

The intuition here is analogous to the elimination of double marginalization though vertical integration (Tirole, 1988, pp. 174–175). Independent access pricing imposes an externality on the other firm and this externality is reflected in retail prices. This externality can be internalized through collusion.

In this section, we have presented some general results for the special case of identical firms. In the next section, we specify more precisely the determination of market shares, which allows us to model the behaviour of asymmetric firms.

IV. Specifying the Market Share

Nontrivial competition between the networks requires some degree of product differentiation. Since telephone services are apparently homogeneous, this requires some justification. One interpretation is that the networks are differentiated by the complementary services they provide. For example, if cable TV networks enter the local telephone market, they will provide a distinctly different bundle of services to that provided by the traditional telephone company. Another firm might distinguish itself by offering superior internet access. Even where the basic services provided are the same, different firms can offer different credit and billing practices.

An alternative motivation for our model of product differentiation is switching costs. Consumers show loyalty to the incumbent so as to avoid the cost of switching. Once they belong to one network, consumers will not switch to the other network unless the price advantage is sufficient to outweigh the costs of switching, which includes the cost of evaluating which network is the cheaper. Switching costs provide the network with some market power. Since modelling switching is complicated, we resorted to a simple model of product differentiation so as to focus on the interconnection problem.

The utility derived from subscribing to network i depends upon

- the size of the network S_i, which determines the number of subscribers reachable on the network,
- the average number of calls q_i to each subscriber on the network,
- the other benefits of belonging to the network θ_i.

θ_i represents all the other benefits of belonging to a particular network other than telephone calls. Note that q_i measures the average number of calls to each subscriber on the network; the total number of calls made is $q_i S_i$.

We assume that consumers preferences are separable (between calls q_i and other benefits θ_i) and can be represented by the quasilinear utility function

$$U(q_i, \theta_i, y) = u(q_i)S_i + \theta_i + y$$

where y represents the consumption of all other goods. The marginal utility of calling decreases with the number of calls, that is $u(q_i)$ is concave. To be specific, we assume that the marginal utility is linear in q, which requires that $u(q_i) = (a - bq_i)q_i$.

Given exogeneous income m, the consumer maximizes utility subject to the budget constraint

$$p_i q_i S_i + y = m$$

where p_i is the price of calls. This implies the demand function for the number of calls per subscriber is

$$q_i(p_i) = \frac{a - p_i}{2b}$$

and the indirect utility function is

$$v(p_i, S_i, \theta_i, m) = \varphi(p_i)S_i + \theta_i + m$$

where

$$\varphi(p_i) = \frac{(a - p_i)^2}{4b}$$

An individual customer will subscribe to network 1 rather than network 2 provided

$$v(p_1, S_1, \theta_1, m) > v(p_2, S_2, \theta_2, m)$$

Given retail prices p_1 and p_2, the market where $s(p_1, p_2)$ of network 1 is the fraction of the population for which $v(p_1, S_1, \theta_1, m) > v(p_2, S_2, \theta_2, m)$. In addition to the network sizes s_i and retail prices p_i, this depends upon the characteristics θ_1 and θ_2, which are exogeneously distributed over the population.

To specify θ_i, we adopt the Hotelling location model of product differentiation (Tirole, 1988, pp. 97–98). We assume that the distinction between the firms is unidimensional. The two firms are located at opposite ends of the unit interval, which their customers are distributed along the interval. For the customer of type $x \in [0, 1]$, the incidental benefits of belonging to network 2 are proportional to x, that is

$$\theta_2(x) = \alpha x$$

α measures the relative importance of non-price competition. If $\alpha = 0$, only price differentials matter and the firm with the lowest prices takes the whole market. As α increases, a firm can price higher than its rival without loosing all its market share.

To allow for asymmetry between the networks, we add an extra factor β to the incidental benefits of belonging to network 1, so that

$$\theta_1(x) = \alpha(1 - x) + \alpha\beta$$

β can be thought of as a measures of "brand loyalty" for network 1, the incumbent. It represents the extra benefits which an entrant must offer to persuade consumers to switch from the incumbent. β can take values between 0 and 1. Clearly, $\beta = 0$ represents the case of symmetric networks. At the other extreme, when $\beta = 1$, even customers of type $x = 1$ prefer to join network 1 when the prices are equal.

With this specification of type θ_i, the utility derived by a consumer of type x from each of the two networks will be

$$v(p_1, S_1, \beta, x, m) = \varphi(p_1)S_1 + \alpha(1 - x) + \alpha\beta + m$$

$$v(p_2, S_2, \beta, x, m) = \varphi(p_2)S_2 + \alpha x + m$$

A consumer of type $\bar{x}$ will be indifferent between the two networks if

$$v(p_1, S_1, \beta, \bar{x}, m) = v(p_2, S_2, \beta, \bar{x}, m) \tag{5}$$

For the simplest case in which x is uniformly distributed on [0, 1], the market share s of network 1 is given by $s = \bar{x}$. Further specification depends upon whether the two networks are interconnected or not. We deal with each case in turn.

1. Interconnection

Recall our assumption that each consumer subscribes to one or other of the networks. Where the networks are interconnected, each customer has access to the combined network. Each customer can call every other customer and $S_1 = S_2 = 1$. Solving (5) for the marginal consumer $\bar{x}$ assuming a uniform distribution of x, the market share of network 1 is

$$s(p_1, p_2) = \begin{cases} 0 & \bar{x} < 0 \\ 1 & \bar{x} > 1 \\ \bar{x} & \text{otherwise} \end{cases}$$

where

$$\bar{x} = \frac{1}{2} + \frac{\beta}{2} + \frac{\varphi(p_1) - \varphi(p_2)}{2\alpha}$$

If there is no brand loyalty ($\beta = 0$) and the networks price identically ($p_1 = p_2$), network 1 will have exactly half of the market. Its market share will exceed one-half to the extent that

- it commands brand loyalty ($\beta > 0$),

- it offers a price differential ($p_1 < p_2$).

2. No Interconnection

Without interconnection, it is no longer the case that every customer can reach every other customer. Each customer must take account of the size of the network when deciding on which network to join. If one network attracts more customers than another, this creates an additional incentive to join the larger network. These network effects can lead to multiple equilibria. In one type of equilibrium, one firm will succeed in capturing the whole market. Its price will be limited to ensure that there is no incentive for any customer to defect to the other network no matter what price the latter charges. In the other equilibrium, the two firms will share the market as in the case of interconnection.

Where the firms share the market, the market share of network 1 is equal to the size of the network $s = S_1$. Similarly, the market share of network 2, $1-s$, is equal to the size of network 2. The utility to the subscriber of type x of subscribing to each network is

$$v(p_1, s, \beta, x, m) = \varphi(p_1)s + \alpha(1-x) + \alpha\beta + m$$

$$v(p_2, s, \beta, x, m) = \varphi(p_2)(1-s) + \alpha x + m$$

Solving (5) for the marginal consumer, assuming a uniform distribution of x, the market share (size) of network 1 is

$$s(p_1, p_2) = \begin{cases} 0 & \bar{x} < 0 \\ 1 & \bar{x} > 1 \\ \bar{x} & \text{otherwise} \end{cases}$$

where

$$\bar{x} = \frac{\alpha(1+\beta) - \varphi(p_2)}{2\alpha - (\varphi(p_1) + \varphi(p_2))}$$

The profit functions of the firms are also different without interconnection. The profit function of firm i is

$$\Pi(p_1, p_2) = s_i^2(p_i - c_i)q_i(p_i)$$

where $s_i(p_1, p_2)$ is the market share of firm i.

Table I. Interconnection agreements in a mature industry with identical firms

	t_1	t_2	p_1	p_2	s	π_1	π_2	CS	TS
Max total surplus	−18.0	−18.0	1.0	1.0	0.50	0.0	0.0	78.0	78.0
Zero tariffs	0.0	0.0	4.4	4.4	0.50	9.6	9.6	53.0	72.1
Max total profits	3.6	3.6	5.5	5.5	0.50	10.1	10.1	47.6	67.9
Nash bargaining	3.6	3.6	5.5	5.5	0.50	10.1	10.1	47.6	67.9
No connection	n.a.	n.a.	3.7	3.7	0.50	4.3	4.3	57.1	65.7
Nash equilibrium	8.8	8.8	7.2	7.2	0.50	8.6	8.6	41.4	58.7

t_i = tariff charged by network i for use by network j.
p_i = consumer price for network i.
s = share, π = profits of network i.
CS = consumer surplus, TS = total surplus (consumer + producer surplus).
$\alpha = 50$, $\beta = 0$.

V. Interconnection Agreements

In this section, we combine the preceding specific model of market share with our general model of firm behaviour to explore the implications of various interconnection arrangements. To enable us to calculate specific outcomes, we impose the following parameter values $a = 10$, $b = 1/2$, $c_1 = c_2 = 1$, $d_1 = d_2 = 0$. This implies the simple demand schedule $q(p_i) = 10 - p_i$, and a monopoly price of 5.5.

We consider two distinct scenarios. In the first, we consider a mature industry with two otherwise identical firms offering distinct products. The application which we have in mind is the situation which may arise in the U.S., where two established networks (the traditional telephone utility and cable TV network) are competing to offer local call telephone service. The auxillary services offered by the two networks are quite distinct, offering scope for competition in dimensions other than price.

The second scenario involves a significant asymmetry, where one firm has an advantage arising from incumbency. The application here is the situation which has arisen in Australia, Britain or New Zealand, where a previous government monopoly has been privatized and the market deregulated, with new entrants wishing to challenge the incumbent for market share.

These two different scenarios are implemented by varying the values of the two remaining parameters α and β.

1. A Mature Industry

Table I summarizes the outcomes of various interconnection arrangements assuming identical firms ($\beta = 0$) and moderate product differentiation ($\alpha = 50$). We present access prices, equilibrium prices and the resulting market shares and profits. We also present two measures of welfare – consumer surplus[6] and total surplus. The outcomes are listed in order of decreasing total surplus.

We now outline how each of the rows is calculated. By Proposition 1, any common retail price can be sustained noncooperatively by appropriate choice of access price. To maximize total surplus requires setting retail price equal to marginal cost $p_i = 1$. The access prices required to induce the firms to noncooperatively choose $p_i = 1$ is calculated to be $t_i = -18$. Computing the resulting profits, consumer and total surplus completes the first row of Table I. Similarly, computing the prices, profits and surplus generated by a common tariff of 0 provides the second row. Joint profits are maximized if both firms choose the monopoly price $p^m = 5.5$. The common tariff necessary to induce this outcome (Corollary 1) is $t_i = 3.6$. This provides the third row.

If there is no connection, each firm monopolizes half the market – serving those consumers which have a closer affinity for their particular product. Each network chooses the monopoly price 3.7 for its half of the market. (This is the bottom row of Table I.) Taking the No Connection outcome as the disagreement point, the Nash Bargaining Solution attempts to share the potential gains from cooperation in accordance with certain axioms (Nash, 1950). Specifically, the Nash Bargaining Solution maximizes the product of the gains from cooperation relative to the disagreement point, that is

$$\max_{t_1,t_2}(\Pi_1 - \pi_1^{\mathrm{NC}})(\Pi_2 - \pi_2^{\mathrm{NC}})$$

where $\pi_i^{\mathrm{NC}} = 4.3$ is the potential profit per firm if there is no agreement. In this symmetric case, the Nash Bargaining Solution is identical with the joint profit maximum.

In each of the preceding outcomes, the access prices t_i are set cooperatively by negotiation or perhaps by regulation. (Retail prices p_i are always determined noncooperatively, although the networks will anticipate their rival's pricing behaviour in the negotiations.) The final outcome listed is the Nash Equilibrium. To compute this outcome, we allow for the possibility tariffs as well as retail prices are set noncooperatively. More precisely, the Nash Equilibrium (Equations (1) and (3)) is the subgame perfect equilibrium in the two-stage game in which tariffs and then prices are set independently and sequentially. The various outcomes for a mature industry are illustrated in Figure 1.

We first observe that there is ample scope for mutual gain from interconnection. If the identical firms attempt to maximize the potential gains from interconnection and split the gains equally, this would lead to the joint profit maximum. This is the Nash Bargaining solution with No Connection as the disagreement point. The firms achieve individual profits of 10.1, compared to 4.3 without connection. Consumers loose dramatically from such an agreement, with consumer surplus falling from

[6] Our consumer surplus measure is in fact indirect utility, including both the area under the demand curve (surplus on calls) plus the other benefits θ of subscribing to the chosen network.

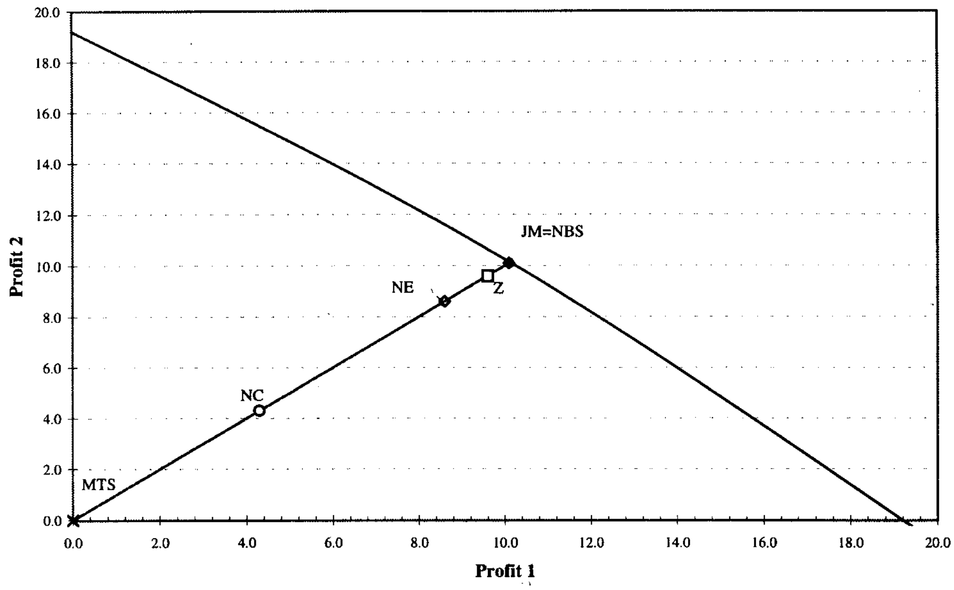

Figure 1. Symmetric industry ($\alpha = 50$, $\beta = 0$).

57.1 to 47.6. Through interconnection, consumers gain the ability to access the combined network. However, this gain is offset by higher prices. Note that, in accordance with Propositions 1 and 2, the firms achieve this outcome by using access prices to collude over retail prices.

The collusive nature of the joint profit maximum outcome suggests the possibility of government intervention to regulate access prices. To maximize total welfare requires large negative access prices. That is, optimal regulation requires each network to pay the other for each call that it receives. This apparently counter-intuitive result is easily explained. Given that equilibrium prices are increasing in tariffs, equilibrium prices fall as tariffs are reduced. A sufficiently large negative tariff induces each firm to price at marginal cost, which is socially optimal. This is analogous to the use of a subsidy to overcome the output distortion of monopoly.

Optimal regulation may be politically or practically impossible. An improvement over unrestrained collusion is to mandate zero tariffs, or in other words "bill and keep", which has often been suggested as a simple interconnection regime. In our earlier paper (Carter and Wright, 1994), we showed that bill and keep may be voluntarily chosen in the international telecommunications setting, where the firms' have monopolies in their own domestic markets. However, there is no reason to expect firms to agree to bill and keep in local call interconnection when they are subject to retail competition, and can use access charges as an instrument of collusion.

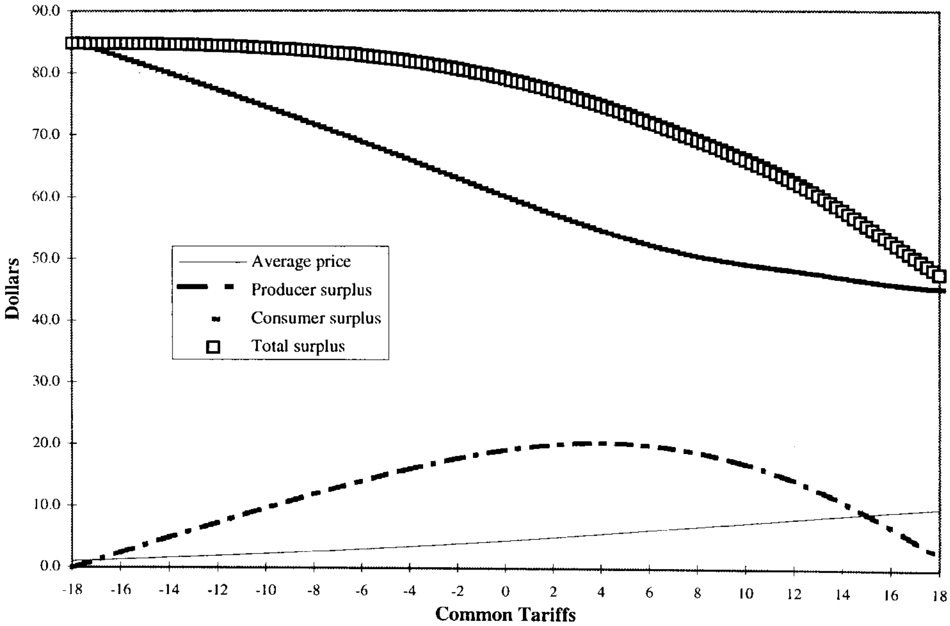

Figure 2. Prices and surpluses for given common tariffs (α = 50, β = 0).

At the other extreme, it is clear that restricting collusion over interconnection is in no one's interest. The Nash equilibrium outcome, where tariffs are chosen independently, is preferable to No Connection for the firms, but significantly worse for consumers. This results from sizeable efficiency losses due to double marginalization in independent action (Proposition 4).

The various outcomes are illustrated in Figures 1 and 2. Figure 1 illustrates the profit possibility set for the two firms, on which are indicated various specific outcomes. In all cases, prices are determined noncooperatively. The 45 degree line shows the outcomes which are possible from symmetric tariffs.[7] Figure 2 presents a cross-section along the 45 degree line (common tariffs). It shows that there is a significant range over which the interests of producers and consumers are aligned.

2. Entry

There are two ways in which we can model the asymmetry which might result where all incumbent firm faces competition from an entrant. The first way is to suppose that customers are more loyal to the incumbent than the entrant. We do this by allowing β to assume positive values, which implies that the entrant (firm 2) must undercut the price of the incumbent (firm 1) to achieve the same level

[7] Each profit level (except the joint profit maximum) can be obtained at two distinct tariff levels.

Table II. Interconnection with entry: Incumbent loyalty

	t_1	t_2	p_1	p_2	s	π	π_2	CS	TS
Max total surplus	−17.9	−18.5	1.3	0.7	0.57	0.0	0.0	84.8	84.8
Zero tariffs	0.0	0.0	4.6	4.2	0.60	11.7	7.4	60.0	79.1
Baumol Willig Rule	2.7	0.0	4.9	5.3	0.65	15.8	4.2	57.0	76.9
Nash bargaining	4.0	3.2	5.4	5.6	0.64	13.5	6.7	54.9	75.1
Max total profits	3.9	3.9	5.5	5.5	0.63	12.7	7.6	54.6	74.9
No connection	n.a.	n.a.	3.7	3.7	0.71	8.5	1.5	63.8	73.9
Nash equilibrium	7.9	11.4	7.2	7.2	0.63	8.5	8.9	48.5	65.9

t_i = tariff charged by network i for use by network j.
p_i = consumer price for network i.
s = share, π = profits of network i.
CS = consumer surplus, TS = total surplus (consumer + producer surplus).
$\alpha = 50$, $\beta = 0.25$.

of demand. The second way we model asymmetry does not rely on any intrinsic preference for one of the firms. Rather, the asymmetry arises out the network effect discussed in Section IV.2. We explore these alternatives in turn.

A. *Incumbent Loyalty*

Table II details the outcomes where firm 1 has a substantial advantage in demand. Not surprisingly, the outcomes favour firm 1. Incumbency creates an asymmetry in bargaining strength which has an impact on the likely outcome of any interconnection agreement. Using the No Connection outcome as the disagreement point, we calculate the Nash Bargaining Solution as a possible voluntary interconnection agreement. Despite the asymmetry, joint profits are maximized by choosing identical tariffs and prices, although this leads to a significantly higher market share and profit for firm 1. Not surprisingly, this outcome is worse for consumers than if prices are set equal to marginal cost (Max Total Surplus). Note, however, the Nash Bargaining Solution is worse for consumers than the status quo with no interconnection, despite the fact that without interconnection subscribers cannot access the whole network. It is not necessarily the case that promoting interconnection benefits consumers.

Two feasible interconnection rules that could be imposed by the Government – zero tariffs and the Baumol–Willig rule – both yield higher consumer welfare than the Nash Bargaining Solution. The Baumol–Willig rule requires that the entrant pay the full opportunity cost of interconnection to the incumbent's network, including any foregone profits. This rule was endorsed by the Privy Council of the House of Lords in a celebrated New Zealand case *Telecom v. Clear*.[8]

[8] Telecom is the recently privatised incumbent telecommunications network in New Zealand and Clear is a new entrant who wished to provide local call services in central business districts. When

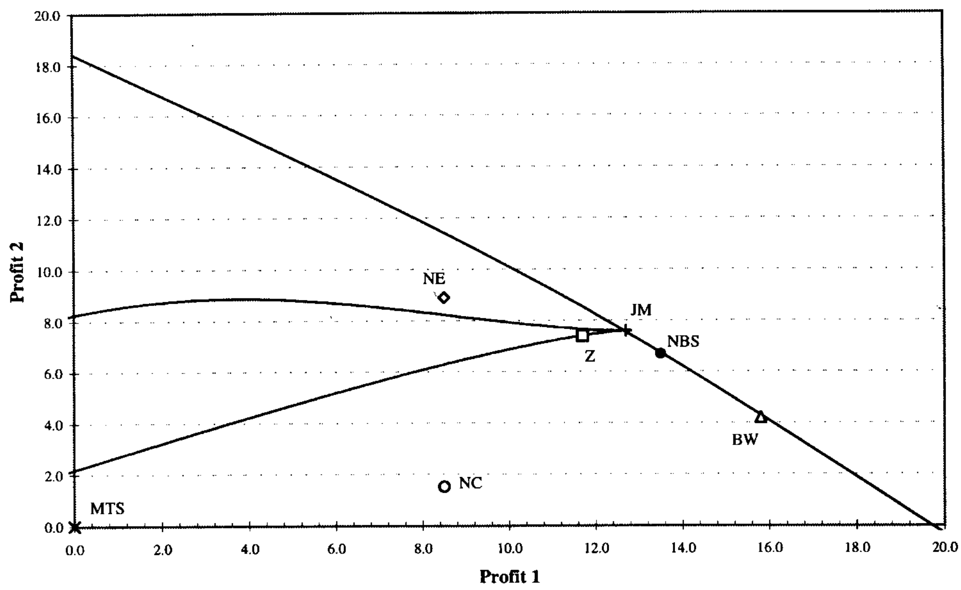

Figure 3. Incumbent loyalty (α = 50, β = 0.25).

Note that the Nash Bargaining Solution and the Baumol-Willig rule both require that the two firms set different tariffs.[9] On the other band, despite the asymmetry, joint profits are maximized if the firms choose identical tariffs and prices. This implies that requiring reciprocity of tariffs is not necessarily in consumers' interests.

The outcomes in the asymmetric case are illustrated in Figures 3 and 4. Figure 3 shows the profit possibility set (assuming non-cooperative retail pricing). The grey curve represents the outcomes from common tariffs. Figure 4 presents a cross-section along this curve.

Telecom offered interconnection on the basis of the Baumol–Willig rule, Clear sued Telecom for "abuse of a dominant position". The initial court found in favour of Telecom. This was reversed on appeal, and reversed again by New Zealand's highest court, the Privy Council.

In this particular instance, the Baumol–Willig rule entitles the incumbent to an interconnection fee equivalent to its retail price before interconnection (3.7) minus the cost savings (1) from having the call terminated by the entrant. For details on the calculation of the Baumol–Willig rule and further discussion of *Telecom v. Clear*, see our companion piece Carter and Wright (1997).

9 Following the Privy Council rule in *Clear v. Telecom*, the two parties recently sighed a voluntary interconnection agreement, which provided for non-reciprocal tariffs. Under the agreement, Telecom will charge Clear 3 cents per minute for completing local calls. Telecom in turn will pay Clear 1 cent per minute, but this will increase to 2 cents by the year 2000. In accordance with our results, the agreed interconnection charge is a substantial portion of the retail price of 4 cents.

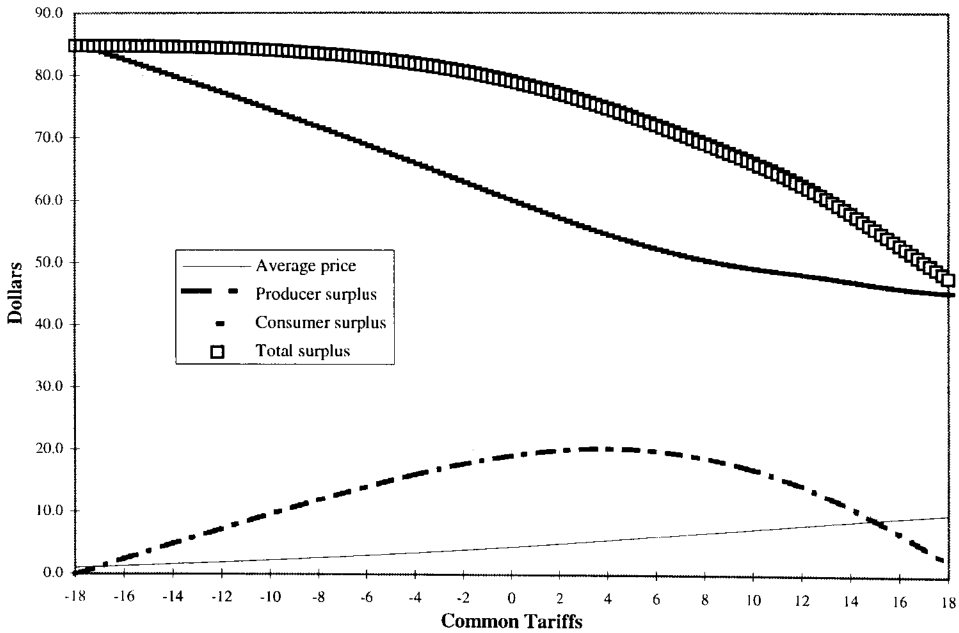

Figure 4. Prices and surpluses for given common tariffs (α = 50, β = 0.25).

B. *Network Effects*

Now consider the case where the firms are intrinsically identical, but there is low product differentiation (α = 25), so that multiple equilibria exist when there is no interconnection. In one equilibrium, the firms share the market equally. In the other two equilibria, one of the firms corners the whole market, and then limit prices to prevent the other firm entering.[10] This generates a sizeable profit for the dominant firm, and creates asymmetry in any bargaining over interconnection.

To be specific, consider the equilibrium in which firm 1 corners the market, setting a limit price of 2.9. This generates more profit for firm 1 (13.6) than if it priced less aggressively, but shared the market with firm 2. Using this as the disagreement point, the Nash Bargaining Solution would generate a profit of 16.5 for firm 1 and 3.1 for firm 2. Even though one firm starts with a monopoly, signing an interconnection agreement is in the interests of both firms. However, interconnection is not in the interests of consumers. Without interconnection, the dominant firm covers the whole market and its price is constrained by the threat of entry. Interconnection (and market sharing) induces less aggressive competition between the two firms since the interconnection agreement enables the firms to bypass antitrust regulation, to collude over prices and act as joint monopolists (Propositions 1 and

[10] In an industry undergoing deregulation, the limitation on pricing of the incumbent might be driven more by the threat of continued regulation rather than the threat of entry.

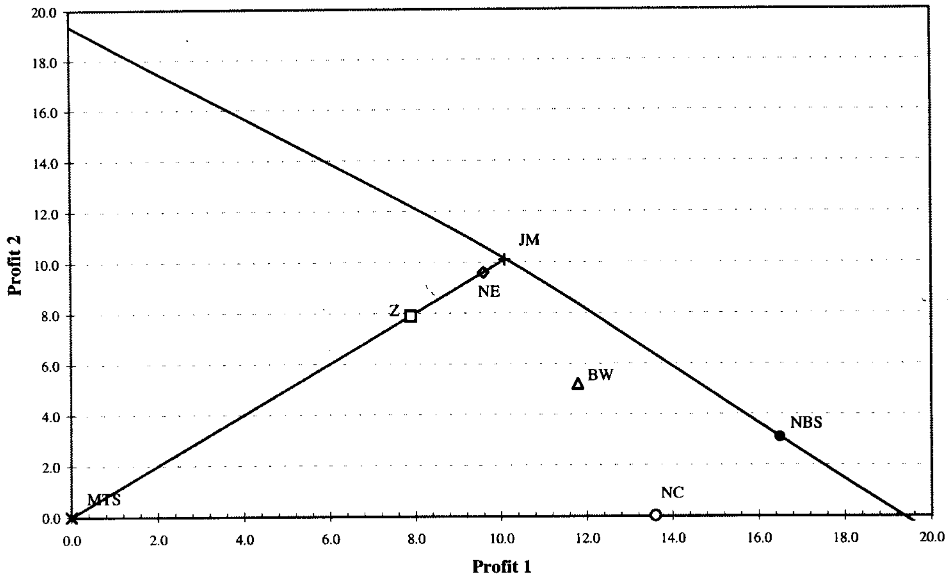

Figure 5. Low product differentiation (α = 25, β = 0).

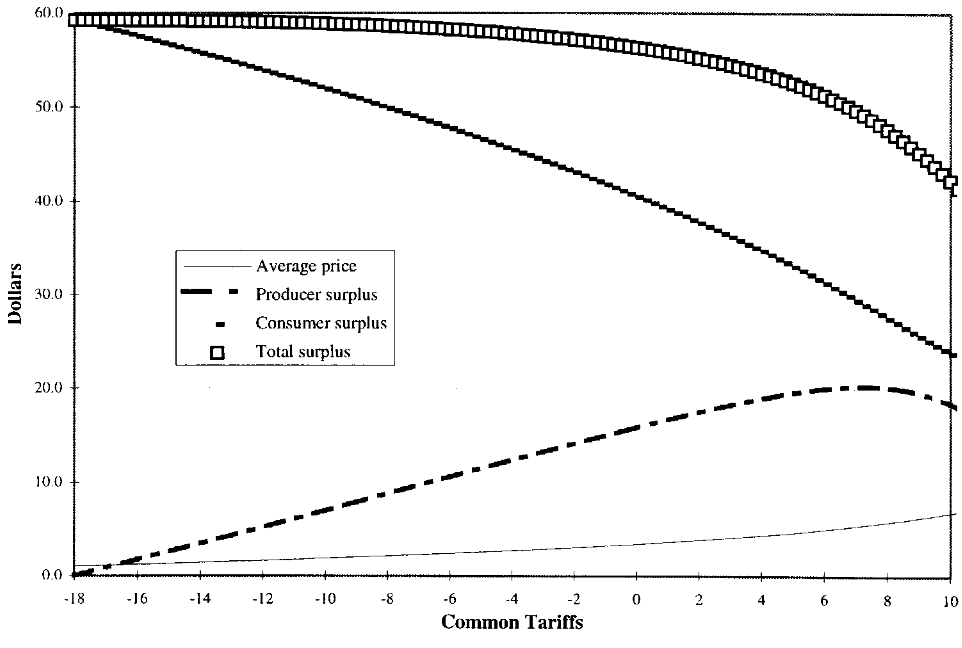

Figure 6. Prices and surpluses for given common tariffs (α = 25, β = 0).

Table III. Interconnection with entry: Low product differentiation

	t_1	t_2	p_1	p_2	s	π	π_2	CS	TS
Max total surplus	−18.0	−18.0	1.0	1.0	0.50	0.0	0.0	59.3	59.3
Zero tariffs	0.0	0.0	3.4	3.4	0.50	7.9	7.9	40.5	56.4
Baumol Willig Rule*	1.9	0.0	3.6	3.8	0.53	11.8	5.2	38.6	55.6
No connection	n.a.	n.a.	2.9	n.a.	1.00	13.6	0.0	37.5	51.1
Nash bargaining*	6.7	1.6	4.5	5.9	0.63	16.5	3.1	30.7	50.3
Max total profits	7.3	7.3	5.5	5.5	0.50	10.1	10.1	28.9	49.2
Nash equilibrium	9.4	9.4	6.5	6.5	0.50	9.6	9.6	28.4	44.3

t_i = tariff charged by network i for use by network j.
p_i = consumer price for network i.
s = share, π = profits of network i.
CS = consumer surplus, TS = total surplus (consumer + producer surplus).
*No connection based on equilibrium where firm 1 has total market.
$\alpha = 25$, $\beta = 0$.

2). While interconnection provides the benefit of increased product variety, this is outweighed by the detriment of higher prices. Table III details the interconnection agreements in this case. They are illustrated in Figures 5 and 6. In this case, the Baumol–Willig rule produces a similar aggregate outcome to bill and keep (zero tariffs). However, the profitability of the two networks is substantially different. Compared to bill and keep, the Baumol–Willig rule secures a higher level of profit for the incumbent.

Product differentiation enables an entrant to secure some customers even if it can only offer access to a small network. As product differentiation (α) declines, network effects assume greater importance. In fact, with our specification, the incumbent would be able to corner the whole market with the monopoly price when

$$\alpha(1-\beta) < \frac{(a/2-(c_1/2-d_1/4))^2}{4b}$$

For the parameter values of this section, the incumbent can choose the monopoly price ($p = 5.5$) and secure the whole market whenever $\alpha < 10.125$. It can capture all the monopoly rents and has no incentive to offer interconnection to any potential entrant. Interconnection terms can be used as a weapon to blockade entry.

Mandating interconnection on reciprocal terms (as provided for in the U.S. *Telecommunications Act*, 1996) would, as we have argued, simply lead the firms to collude over their access tariffs to again achieve the monopoly price. In this case, all that is achieved by mandatory interconnection is the transfer of monopoly rents from the incumbent to the entrant. However, we should note that low product

Table IV. Interconnection with marginal cost price regulation

	t_1	t_2	p_1	p_2	s	π	π_2	CS	TS
Max total surplus	0.0	0.0	1.0	1.0	0.50	0.0	0.0	78.0	78.0
Zero tariff	0.0	0.0	1.0	1.0	0.50	0.0	0.0	78.0	78.0
Nash equilibrium*	7.5	7.5	4.8	4.8	0.50	9.9	9.9	51.2	70.9
Nash bargaining	9.0	9.0	5.5	5.5	0.50	10.1	10.1	47.6	67.9
Max total profits	9.0	9.0	5.5	5.5	0.50	10.1	10.1	47.6	67.9
No connection	n.a.	n.a.	1.0	1.0	0.50	0.0	0.0	57.8	57.8

t_i = tariff charged by network i for use by network j.
p_i = consumer price for network i.
s = share, π = profits of network i.
CS = consumer surplus, TS = total surplus (consumer + producer surplus).
*Nash equilibrium in tariffs assuming prices are regulated.
$\alpha = 25$, $\beta = 0$.

differentiation exacerbates the existence problem.[11] For low α, there may in fact be no equilibrium with interconnection. To the extent that existence problem is a real world phenomenon, we can say little about the welfare implications of mandatory interconnection in such cases.

C. *Regulated Market*

The focus of this paper has been to examine the implications of different interconnection agreements when retail markets are deregulated. However deregulation in telecommunications at the local level is a recent phenomenon. For this reason it is interesting to see low our model of two way interconnection behaves when retail prices are regulated. We focus on one simple type of regulation, marginal cost pricing regulation.

Table IV details the outcomes of various interconnection agreements in a mature industry. With zero interconnection costs, the welfare maximizing tariffs are achieved by bill and keep, which implies retail prices will be set at the marginal cost to each firm of making calls. However, with no regulation of interconnection, the firms can undermine the retail price regulation by charging each other access charges, as we showed in Proposition 3.

This result has a number of policy implications. Firstly, if the government has to choose between regulating either the retail price or the interconnection fee, it should choose the latter. Regulating the retail price alone gains nothing if the interconnection fees remain unregulated. Secondly, if the retail price is regulated, the payoff to regulating the interconnection fee is substantially increased compared to the situation where the retail price is deregulated. Finally it is again not necessarily

[11] The supplementary appendix (available from the authors) contains some further remarks on the existence problem.

the case that requiring interconnection enhances welfare. One possible voluntary interconnection agreement is the Nash Bargaining Solution, which maximizes joint profits. Compared to the No Connection outcome, this increases the profits of the firms, but decreases consumer surplus. What the consumers' gain through their ability to access the combined network is more than offset by the higher prices which they are charged, despite the regulation.

As we have seen, much of the logic of two-way interconnection in deregulated markets carries over to marginal cost price regulations. However, there is at least one important difference. Baumol-Willig tariffs now give the socially optimal outcome. This is not surprising, since without interconnection, firms are forced to price at their marginal cost. This illustrates the point that Baumol-Willig rule is only appropriate when output markets are regulated.

VI. Conclusion

Our analysis throws some doubt on the ability of competition to achieve efficient outcomes in network industries. The real difficulty is not that the competitors find it difficult to reach an interconnection agreement, rather that their agreement is likely to be damaging to consumers. Interconnection fees provide the networks with a legitimate instrument of collusion. Collusion over retail prices (price-fixing) is illegal *per se* (in most jurisdictions). However, collusion (negotiation) over the setting of interconnection fees is expected and indeed encouraged. The networks can use interconnection fees to effectively exploit their monopoly power and vicariously collude on final retail prices. Furthermore, restricting this collusion is not desirable. Acting independently, firms would be inclined to set higher tariffs. Since retail prices are increasing in tariffs, this would lead to even higher prices and less efficiency.

This upsets the balance between competition and efficiency which lies at the heart of competition policy. The normal tradeoff for competition policy is between competition and allocative efficiency on the one hand and productive efficiency on the other. In network industries, the need for interconnection severs the link between competition and allocative efficiency. Competition does not necessarily promote allocative efficiency, since the networks can use interconnection charges as instruments of collusion and exploit their joint monopoly power.[12] Where the technology exhibits increasing returns to scale or requires duplication of facilities, introducing competition may also lead to productive inefficiency. Networks may truly be natural monopolies.

On the face of it, this suggest a role for government intervention in network industries. A first best solution could be attained by regulating interconnection charges. But, to appropriately regulate interconnection charges requires all the information necessary to compute optimal retail prices. The usual arguments against

[12] To the extent that the networks offer differentiated products, consumers will benefit from increased variety with competition.

regulation – asymmetric information, regulatory capture – apply equally to the regulation of interconnection charges. The first best regulatory solution is unlikely to be practical.

A second best regulatory solution would involve placing some restraints on negotiated tariffs. For example, the 1996 U.S. *Telecommunications Act* mandates reciprocal compensation arrangements. In particular, this requires that interconnection fees be equal. Requiring a common tariff does not limit the firms' ability to collude over tariffs and push up retail prices. In fact, by eliminating the conflict of interest between the firms, it may make it easier for the firms to exploit their joint monopoly power at the expense of consumers. Where there is significant asymmetry between the firms, forcing reciprocity will force a realignment of retail prices, benefiting the consumers of one firm at the expense of others. There appears to be no economic justification for requiring reciprocity.

On the other hand, bill and keep has much to recommend it as a second best regulatory solution. If the marginal costs of providing interconnection are significant, bill and keep is equivalent in our framework to levying negative tariffs. Excluding detailed regulation, this is as close as we are likely to get to the first best optimum. For this reason, bill and keep would seem to be a simple welfare-enhancing regulatory mechanism.

Thus, we arrive at a similar policy conclusion to Williams (1995) although for different reasons. Williams argues that, provided the there is no serious imbalance of calls between the networks, access prices should be zero.

> If public policy is concerned to foster the competitive provision of local exchange services it would do well to base its reasoning on the assumption of symmetry. This assumption would bias the regulator in favour of zero interconnection charges.

This conclusion was echoed in a report prepared by the Ministry of Commerce and the Treasury in New Zealand in response to the Clear-Telecom dispute over interconnection. This report claimed:

> If the networks are relatively similar in terms of their customer base technology and pricing structure, the imbalance of calls is likely to be very much smaller than the total number of calls passing across the interconnection. In such circumstances the absolute level of interconnection call charges matters very little as, on average, the net interconnection charge paid by either network is zero.

While this sounds plausible, it overlooks the role that interconnection charges play in determining retail prices. Our results show that access charges do matter, even when the firms are similar and the flow of calls is balanced.

Bill and keep has the additional advantage of having low transaction costs, eliminating the need for accounting and billing between the networks. Unfortunately, imposing bill and keep raises a difficult legal and ethical issue in dealing with a privatised incumbent. Their existing network is a private asset – imposing bill and keep requires them to extend free use of their network to a rival, which seems tantamount to a form of expropriation. It remains for future work to explore the implications of bill and keep for the incentive of firms to invest in network capital presuming two way interconnection.

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