Market Concentration and Incentives to Discriminate Against Rivals in Network Industries

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Against Rivals in Network Industries

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Abstract

I examine the effects of market concentration on interconnection in network industries. Using Cournot interactions, each network chooses quantity, quality for communications within the provider's own network, which I call internal quality, and quality for communications between the provider's network and other networks, which I call external quality. Larger networks choose higher internal quality than do smaller networks. All networks choose lower external quality when connecting with smaller networks. Large networks and small networks choose identical external quality when interconnecting with each other. Lastly, incumbent providers are willing to raise rivals' per customer costs, but never interconnection costs.

1. Introduction

The liberalization of telecommunications markets has been marked by a number of mergers and alliances, some of which have been record setting. In 1995, US telecommunications businesses were involved in acquisitions worth $39.1 billion. This increased to $154.8 billion by the first half of 1998. Global mergers and acquisitions in the information technology, communications, and media industries jumped 87 percent between 1997 and 1998 to $488.8 billion (Capron and Mitchell, 1997; Broadview, 1998). Telecommunications accounted for 20% of all merger and acquisition activity worldwide in 1999. (Wall Street Journal, July 19, 2000, p. A18) Recent examples of mergers and alliances include the merger of Bell Atlantic with NYNEX in 1997, and then with GTE in 2000; SBC's acquisition of Pacific Telesis in 1997, Southern New England Telephone in 1998, and Ameritech in 1999; AT&T and British Telecom's formation of a global joint venture in 1999; WorldCom's purchase of MCI in 1998; and Vodafone's acquisition of AirTouch in 1999 and Mannesmann in 2000.

Competition regulators, utility regulators, and others often raise concerns that telecommunications mergers might decrease competition. Such concerns prompted the European Union (EU) to place restrictions on Global One and on the now defunct British Telecom and MCI alliance. (McDavid, 1997) The EU also required MCI to divest a portion of its Internet business as a condition of approving WorldCom's purchase of MCI (Crémer, Rey, and Tirole, 1999). The EU halted WorldCom's planned purchase of Sprint because the EU's competition commissioner believed that the merged company would dominate transmission of information over the Internet. (Financial Times, July 14, 2000, p. 20). Olbeter and Robison (1999) argue that market concentration in the Internet backbone in the US results in some rural states having little access to the Internet. In contrast, in a joint study, the US Department of Commerce and the US Department of Agriculture (2000) found that the high cost of broadband local lines, not access to the Internet, causes rural areas to have less broadband access than urban areas. Crémer et al. (1999) argue that larger Internet firms have an incentive to lower the quality of their interconnection with smaller rivals.

In contrast, some research indicates that telecommunications mergers can improve market efficiency. Jamison (1999a) explains how regulation in the US and government ownership of service providers elsewhere have held the industry to an antiquated structure for decades. Market liberalization is forcing incumbent companies to restructure to meet the new economic realities or risk failure. Weisman (1999) shows how mergers among incumbent local exchange companies make it more likely for the merged company to compete against other incumbent local exchange companies. Galbi and Keating (1996), Jasinski (1997), and Jamison (1998 and 1999a) explain how network providers become global to attract large multinational communications customers who want their international communications to be provided by an integrated multinational network. Firms such as AT&T and WorldCom meet this demand by establishing local networks in multiple countries and integrating these local networks with their international networks. Jamison (1999b) shows how this process can increase competition and improve welfare.

This paper extends this research by examining market concentration in the Internet. This is one of the issues that caused the collapse of the WorldCom-Sprint merger, the other issue being the US Department of Justice’s concern that the combined company would have 27% of the US consumer long distance market. (Wall Street Journal, July 5, 2000, p. A23) I examine an oligopoly model in which firms choose network quality for internal communications (which I call internal quality) and interconnection quality for communications between networks (which I call external quality). I show that firms base their quality choices on network size, customer value of interconnection, and the cost of interconnection. Networks choose lower external quality when connecting with a smaller network than when connecting with larger networks. I find that larger networks and smaller networks choose the same external quality when interconnecting with each other. I also find that incumbent firms will raise entrants' quantity costs, but will never sabotage rivals by raising the rivals' costs of interconnection.

I develop and explain my results by applying a static oligopoly model in which firms have identical cost structures for quality, but not necessarily for quantity. When a cost asymmetry exists, it results from an incumbent firm having a network that is larger than other firms' networks at the start of the game. Also, an incumbent can raise its rivals' costs, for example by delaying access to essential facilities. I apply a two-stage game in which an incumbent chooses whether to sabotage rivals in the first stage. Firms compete for customers and seek to maximize their individual profits in the second stage by simultaneously choosing quantity, internal quality, and external quality. In contrast with Crémer et al. (1999), who assumed that internal quality was fixed, I allow firms to choose internal quality. This generalization allows an expanded examination of firms' quality choices.

As a benchmark, I first examine a case in which three identical firms compete in a single market. I find that the firms make identical quality choices. I next examine a case in which two firms serve a single market and compete in this market against a third firm that has a monopoly in another market. I show that a Nash equilibrium exists in this setting wherein the firms choose identical external qualities. Furthermore, each smaller firm chooses an internal quality that is lower than its external quality for interconnecting with the larger firm. Smaller firms make these choices because the number of customers reached through a network affects firms' quality choices and the smaller firms' smaller quantities of customers are less valuable than the larger firm's larger number of customers. Also, because I assume that smaller firms are symmetric in size, the smaller firms choose external qualities for interconnecting with each other that are equal to their internal quality choices. I then examine a case in which the first two firms can enter the former monopoly market, but are subject to a cost disadvantage because of the incumbent’s established network. I show that, as in the first situation, firms agree upon external quality and that the incumbent's quantity choice is larger than its rivals’ quantity choices. Finally, I examine whether the incumbent would sabotage its rivals by raising their costs. I show that the incumbent may raise its rivals’ costs for quantity in certain situations, but the incumbent never raises its rivals’ costs for interconnection, even when it can do so costlessly. The incumbent is unwilling to raise rivals’ interconnection costs because the higher costs would cause the rivals to choose an external quality that is below the incumbent’s optimal choice.

My results conflict with the findings of Crémer et al. (1999). Their model assumes that differences in firm size result from differences in installed customer bases, which they call attached customers. Attached customers are customers who cannot change service providers nor their quantities purchased for the duration of the game. Firms choose external quality based in part on the value of allowing their own customers with connectivity to rivals' attached customers. Crémer et al. (1999) assume that firms must meet the quality demands of new customers, but incur no penalty for ignoring the preferences of their own attached customers. As a result, when two firms interconnect, the firm with the larger number of attached customers chooses a lower external quality than does its rival, which has the lower number of attached customers. Crémer et al. (1999) support their assumptions regarding attached customers by explaining that customers sign long-term contracts and quality is difficult to observe. However, contracts that allow firms to ignore customer preferences should not be part of a Nash equilibrium because the customers would be better off never signing such contracts. Furthermore, if quality is hard to observe, it is hard to observe for both new and existing customers, so it is unclear why firms must serve the quality preferences of new customers while ignoring the quality preferences of existing customers. To avoid these difficulties, I assume that asymmetries in firm size results from access to monopoly markets and cost asymmetries. I find that asymmetry in firm size in my model does not result in the interconnection problems identified by Crémer et al. (1999).

The analysis proceeds as follows. Section 2 describes the model. Section 3 presents the benchmark case in which three identical firms compete in a single market. Section 4 presents the case in which one of the firms has a monopoly in another market. Section 5 considers the case of entry into a formerly monopoly market and the incumbent's incentives to sabotage rivals. Section 6 is the conclusion. Proofs are in the Appendix.

2. The Model

I consider an extension of a model developed by Crémer et al. (1999). There are two markets, *A* and *B*, for network communications and three firms. Markets are distinct because they are separated by geography. There are q_μ customers in market $\mu \in \{A, B\}$. Network providers compete for customers in a single period. $q_{i,\mu} \geq 0$ will denote the number of customers that firm *i* serves in the market. I assume that q_μ is sufficiently large in each market to ensure that there are unserved customers in equilibrium; i.e., in equilibrium $q_\mu > q_{1,\mu} + q_{2,\mu} + q_{3,\mu}$.

Customers are identical in each market and a customer of type $\tau \in [0, \bar{\tau}]$ (where $\bar{\tau}$ is the same in both markets) obtains a net surplus from buying from firm *i* at price $p_{i,\mu}$ equal to $\tau + s_{i,\mu} - p_{i,\mu}$, where $s_{i,\mu}$ denotes the value that the customer places on *i*'s network. I assume that τ is uniformly distributed.[1] Customers desire to communicate with customers in both markets, so $s_{i,\mu}$ is given by

$$s_{i,\mu} = v \sum_{j=1}^{3} \sum_{\rho=A}^{B} \theta_{i,j} q_{j,\rho}. \tag{1}$$

$v \in (0, 1/4)$ is a parameter that reflects the constant marginal value that customers place on network communications of a given quality. This linearity assumption of value follows Crémer et al. (1999) and implies that, except for the firms' quality choices, each customer of type τ is indifferent with respect to which customers the τ-type customer communicates. Because customers always place positive value on being able to communicate with additional customers, $s_{i,\mu}$ is increasing in quantity. Because firms

[1] This assumption results in a linear demand curve.

connect networks across markets, $s_{i,\mu}$ for customers in one market is increasing in quantity for both markets. $\theta_{i,i} \in [0, 1]$ is firm *i*'s internal quality choice and $\theta_{i,j} \in [0, 1]$ is the quality of external interconnection with *j*'s network for $j \neq i$. For simplicity, I assume that each firm chooses a single internal quality and, for each network with which it interconnects, the firm chooses a single external quality. In other words, if firm *i* serves both markets, it provides a single quality interconnection $\theta_{i,j}$ for firm *j*, as opposed to providing different quality interconnections for each market. I further assume that the value firm *i*'s customers place on communicating with customers of firm *j* is independent of the quality offered for communicating with customers of firm *k*, $k \neq j$. I assume that networks are homogeneous except for the providers' quality choices. One implication of these assumptions is that, if networks have the same number of customers and offer the same quality levels, then customers are indifferent between firms.[2]

To focus the analysis on how network providers can affect the quality of each other's service offerings, I restrict the quality choices to such things as technical features and reliability that firms can affect when interconnecting their networks. For example, America Online offers proprietary content and functions for its own users and not for users of other Internet Service Providers. I omit other aspects of quality, such as bandwidth for customer network access, which are unaffected by interconnection.

Because only one quality choice can prevail for each network interconnection, the firm with the lowest external quality preference determines the interconnection quality;

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[2] Technically, the term $q_{i,\mu}$ in (1) should be $q_{i,\mu} - 1$ because customers do not obtain value from accessing themselves. I suppress the –1 and assume that q is sufficiently large that it does not affect the results. If the –1 were included, its effect would be to lower each firm's internal quality relative to external quality.

i.e., the quality of the interconnection between i and j is $min\{\theta_{i,j}, \theta_{j,i}\}$. For example, if one firm chose a capacity of 45 megabits per second and the other chose a capacity of 30 megabits per second, only 30 megabits per second of information could be passed between the networks. The proof to Lemma A1 in the Appendix shows that this results in an infinite number of Nash equilibria. In all instances in this paper, the interconnecting firms make identical choices when optimizing external quality, so I assume that this is the equilibrium choice.

Customers make their purchasing decisions after firms have made their quality and quantity choices. I assume no price discrimination and further assume that prices adjust to firms' and customers' equilibrium choices. Lemma 1 describes customers' network preferences in equilibrium.

Lemma 1. Given the assumptions of the model, each customer of type τ is indifferent between networks at equilibrium; i.e., $\tau + s_{i,\mu} - p_{i,\mu} = \tau + s_{j,\mu} - p_{j,\mu}$ for every i, j = 1, 2, 3 and $i \neq j$.

It follows from Lemma 1 that if firm i attracts customers, it has a quality-adjusted price

$$p_{i,\mu} - s_{i,\mu} \equiv \overline{p}_{\mu}. \qquad (2)$$

I define the marginal customer to be the customer that, in equilibrium, is indifferent between buying and not buying network service. Such a customer exists because I assume that $\tau \in [0, \overline{\tau}]$, costs are strictly positive, and v, the constant marginal value of connectivity, is sufficiently large relative to firms' costs to ensure that $q_{i,\mu} > 0$ for every firm. At equilibrium, the marginal customer will receive zero net surplus and so will have a value of $\tau = \overline{\mathrm{p}}_{\mu}$. Because the distribution of customers is uniform, the quantity of customers that firms choose to serve in equilibrium is simply the total number of customers that lie between the upper bound of customer preferences and $\overline{\mathrm{p}}_{\mu}$. Normalizing the density of customers to 1 in each market, the quantity of customers served in market μ is

$$\sum_{i=1}^{3} q_{i,\mu} = \overline{\tau} - \overline{p}_{\mu}. \tag{3}$$

Combining (1), (2), and (3) gives the customers' inverse demand curve for firm *i* in market μ

$$p_{i,\mu} = \overline{\tau} - \sum_{j=1}^{3} q_{j,\mu} + v\left(\sum_{j \neq i}^{3} \theta_{i,j} q_{j,A} + \theta_{i,i} q_{i,A} + \sum_{j \neq i}^{3} \theta_{i,j} q_{j,B} + \theta_{i,i} q_{i,B} \right). \tag{4}$$

Existing (incumbent) firms have identical innate cost functions. New entrants have a cost penalty because they must build networks. Actual costs for some firms may exceed innate costs because incumbents in formerly monopoly markets can raise rivals' costs. For example, incumbents may provide rivals with inferior access to essential facilities or withhold critical network information. (Economides, 1998) Entrants cannot raise incumbents' costs in this way because they do not have essential facilities nor do they have network information that the incumbent does not have. Also, incumbents might deny access to rights of way be either refusing access or by using all the capacity of the rights of way. Incumbents might also require points of interconnection to be in locations that are far from its rivals' customers, causing the rivals to incur extra costs to reach their customers. The US Federal Communications Commission recently fined GTE $2.7

million for allegations that GTE denied rivals access to GTE facilities for locating equipment. Incumbents might also delay rivals' market entry by raising legal objections.

Because the quality choices are restricted to quality that can be affected by interconnection, the costs of adding customers and of providing quality are separable. Incumbents incur a constant marginal cost $c > 0$ of serving a customer. Entrants' marginal costs are $c + c_0 > 0$, where $c_0 \geq 0$. For simplicity, I assume a symmetric, continuous cost function $K(\theta_{i,j}) \geq 0$ of providing quality $\theta_{i,j} \in \{\theta_{i,1}, \theta_{i,2}, \theta_{i,3}\}$ for $i = 1, 2, 3$. Quality costs are separable from quantity costs and among connections. The assumption that quality costs are separable is reasonable because it is common for telecommunications firms to have dedicated network equipment for each network interconnection and to have separate equipment for connections for its own customers. I further assume that $K(\theta_{i,j}) > 0$ for all $\theta_{i,j} > 0$, $K(0) = 0$, $K_\theta > 0$, $K_{\theta\theta} > 0$, and $K_{\theta\theta\theta} < 0$.

Extending Economides' (1998) model of raising rivals' costs and Mandy and Sappington's (2000) model of sabotage, I assume that an incumbent and former monopolist, which I call firm 1, in market A incurs a cost $\chi(r_q) \geq 0$ to raise firm 2's and firm 3's costs by $r_q q_{2,A}$ and $r_q q_{3,A}$, respectively.[3] I assume $\chi(r_q)$ is continuous, $\chi(r_q) > 0$ if $r_q > 0$, $\chi(0) = 0$, $\chi_r > 0$, $\chi_{rr} > 0$, and $r_q \geq 0$. Furthermore, firm 1 incurs a cost $\phi(r_\theta) \geq 0$ to raise rivals' costs of external quality for interconnecting with firm 1 by $K(\theta,r_\theta) - K(\theta) \geq 0$, where $\phi(r_\theta)$ is continuous, $\phi(r_\theta) > 0$ if $r_\theta > 0$, $\phi(0) = 0$, $\phi_r > 0$, $\phi_{rr} > 0$, $K(\theta,r_\theta) > K(\theta)$ if $r_\theta > 0$, $K(\theta_{i,j},0) = K(\theta_{i,j})$, $K_r > 0$, $K_{rr} > 0$, and $r_\theta \geq 0$ for all $i, j = 1, 2, 3$. As a result, firm 1's

[3] Economides (1998) assumed that raising rivals' costs was costless for the incumbent. This can lead to the incumbent preventing all entry, so I impose a cost on the incumbent.

cost of serving $q_{1,A} + q_{1,B}$ customers with quality choices $\boldsymbol{\theta}_1 = \{\theta_{1,1}, \theta_{1,2}, \theta_{1,3}\}$ is

$$C(q_{1,A}, q_{1,B}, \boldsymbol{\theta}_1) = c(q_{1,A} + q_{1,B}) + \sum_{j=2}^{3} K(\theta_{1,j}) + K(\theta_{1,1}) + \chi(r_q) + \phi(r_\theta)\,, \tag{5}$$

and rival j's cost of serving $q_{j,A} + q_{j,B}$ customers, $j \neq 1$, is

$$C(q_{j,A}, q_{j,B}, \boldsymbol{\theta}_j) = (c + c_0 + r_q)q_{j,A} + cq_{j,B} + K(\theta_{j,1}, r_\theta) + \sum_{k=2}^{3} K(\theta_{j,k}).$$

I assume a two-stage game in which the incumbent chooses its cost-raising activities and then firms compete in quantity and quality. Presuming Nash behavior, each firm takes its rivals' quantity and quality choices as given when it chooses its quantity and quality levels. Therefore, (4) and (5) imply that firm 1's profit maximization problem can be written as:

$$\begin{aligned} \max_{q_{1,\mu}, \boldsymbol{\theta}_1, r_q, r_\theta} \pi_1 = & \left[\bar{\tau} - c - \sum_{j=2}^{3} (1 - v\theta_{1,j}) q_{j,A} - (1 - v\theta_{1,1}) q_{1,A} + v \sum_{j=1}^{3} \theta_{1,j} q_{j,B} \right] q_{1,A} \\ & + \left[\bar{\tau} - c - \sum_{j=2}^{3} (1 - v\theta_{1,j}) q_{j,B} - (1 - v\theta_{1,1}) q_{1,B} + v \sum_{j=1}^{3} \theta_{1,j} q_{j,A} \right] q_{1,B} \\ & - \sum_{j=1}^{3} K(\theta_{1,j}) - \chi(r_q) - \phi(r_\theta) \\ \text{subject to} \quad & \theta_{1,j} \in [0,1] \quad \text{for } j = 1, \ldots, 3 \\ & r_q, r_\theta \geq 0 \\ & q_{1,\mu} \geq 0 \qquad \text{for } \mu = A, B. \end{aligned} \tag{6}$$

Assuming for simplicity that $c_0 = 0$ in market B, firm j's profit maximization problem, $j \neq 1$, can be written as:

$$\max_{q_{j,\mu},\boldsymbol{\theta}_j} \pi_j = \left[\bar{\tau} - c - c_0 - r_q - \sum_{k \neq j}^{3} (1 - v\theta_{j,k}) q_{k,A} - (1 - v\theta_{j,j}) q_{j,A} + v \sum_{k=1}^{3} \theta_{j,k} q_{k,B} \right] q_{j,A}$$
$$+ \left[\bar{\tau} - c - \sum_{k \neq j}^{3} (1 - v\theta_{j,k}) q_{k,B} - (1 - v\theta_{j,j}) q_{j,B} + v \sum_{k=1}^{3} \theta_{j,k} q_{k,A} \right] q_{j,B}$$
$$- \sum_{k \neq i}^{3} K(\theta_{j,k}) - K(\theta_{j,i}, r_\theta) \qquad (7)$$

subject to $\theta_{j,k} \in [0,1]$ for $k = 1,2,3$

$q_{j,\mu} \geq 0$ for $\mu = A, B.$

To ensure internal solutions that satisfy second order conditions, I assume $K_\theta(1) > \frac{v(\bar{\tau} - c)^2}{4(1-2v)^2}$, $K_{\theta\theta}(1) > \frac{2v^2(\bar{\tau} - c)^2}{(1-2v)^3}$, and $\bar{\tau} - c - c_0 > 0$. Also, throughout the paper, I assume that identical firms choose identical levels of quantity.

3. Symmetric, Single Market Case

In this section I consider the case where three identical firms compete in a single market, which I call market *B*. I designate the firms as 2, 3, and 4 and, because no firm is an incumbent market *B*, the firms have symmetric cost functions and no firm can raise its rivals' costs. I consider the equilibrium in which these identical firms choose identical levels of quantity. Proposition 1 provides this section's primary result.

Proposition 1. In the symmetric, single market setting, each firm sets all of its external quality levels equal to its selected internal quality level; i.e., $\theta^*_{i,i} = \theta^*_{i,j}$ for $j \neq i$, for all i, j = 2, 3, 4.

In choosing external quality, each firm considers its quantity choice, the quantity choice of the network with which it is interconnecting, and *v*, the value a customer places on communicating with another customer; i.e., $\theta^*_{i,j} = K_\theta^{-1}\left(vq^*_{i,B}q^*_{j,B}\right)$. Firms consider their own quantity choice because this determines the number of customers that are willing to pay prices that reflect the value of the external quality. Firms consider the other firm's quantity choice because more customers on other networks increase the value of the interconnection. Because firms' have symmetric quantity choices, they have symmetric external quality choices. Furthermore, firms determine internal quality based on *v* and their quantity choice squared; i.e., $\theta^*_{i,i} = K_\theta^{-1}\left(vq^*_{i,B}q^*_{i,B}\right) = K_\theta^{-1}\left(v\left(q^*_{i,B}\right)^2\right)$. Their quantity choice is squared because more customers on the firm's own network increase the value of the network, and each customer represents someone who will pay a price that reflects that value. Because in a symmetric equilibrium, all quantity choices are equal, internal quality equals external quality.

From Proposition 1, the symmetric equilibrium quantity for a representative firm *i* is:

$$q^S_{i,B} = \frac{\bar{\tau} - c}{4\left(1 - v\theta^S\right)}, \text{ where}$$

$$\theta^S = G\left(v\left(q^S_{i,B}\right)^2\right).$$

Firms' that serve more customers also choose higher quality.

4. Monopolist Entry into a Competitive Market

In this section I consider the case where firm 1 has a monopoly in market *A* and firms 1, 2, and 3 compete in market *B*. This might represent a situation where the monopoly has merged with firm 4 to enter market *B*. Costs are symmetric in market *B* and, because no firm is an incumbent in market *B*, no firm can raise its rivals' costs. As in the symmetric, single market case, I consider the equilibrium in which identical firms' choices are symmetric. Proposition 2 provides this section's primary result.

Proposition 2. In the setting in which a monopolist from one market enters a second market which is competitive, the monopolist and its rivals choose the same levels of external quality for a given interconnection; i.e., $\theta^*_{i,j} = \theta^*_{j,i}$ for $j \neq i$, for all i, j = 1, 2, 3.

Each firm in the monopolist entry setting considers its quantity choice and the quantity choice of the network provider with which it is interconnecting when choosing external quality. Because value increases with the number of customers reached through an interconnection, the firms make symmetric external quality choices even though their quantity choices may be asymmetric. The monopoly firm does not strategically degrade the quality of its interconnection with smaller rivals. Corollary 1 further describes firms' quality choices. Lemma 2 is useful for Corollary 1.

Lemma 2. In the monopolist entry setting, the monopolist in market *A* chooses a greater quantity in market *B* than does its rivals; i.e., $q^*_{1,B} > q^*_{j,B}$ for all $j \neq 1$.

Firm 1 chooses a higher quantity in market *B* than does either of its rivals because it internalizes some network externalities. In other words, its quantity choice in market *B* has synergistic effects with its quantity choice in market *A* -- higher output in market *B* increases the value of the monopolist's network in market *A*. Furthermore, higher output in market *A* increases the value of firm 1's network in market *B*.

Corollary 1 describes the firms' internal and external quality choices.

Corollary 1. In the monopolist entry setting:

a. The monopolist's internal quality choice exceeds its external quality choices;

b. The rivals implement an internal quality below the external quality they implement for interconnecting with the monopolist;

c. The rivals implement an internal quality that is equal to the external quality they implement for interconnecting with each other; and

d. The rivals implement an external quality for interconnecting with each other that is lower than the external quality they implement for interconnecting with the monopolist.

That is to say, $\theta^*_{1,1} > \theta^*_{1,j} = \theta^*_{j,1} > \theta^*_{j,j} = \theta^*_{j,k}$ for $j \neq k$, for all j, k = 2, 3.

The monopolist provides the highest quality because its optimal quantity choices are higher than its rivals' optimal quantity choices. These higher quantity choices make the monopolists competitive network more valuable than its rivals' networks. Furthermore, for connection to a network of a given size, the monopolists' higher quantity choice makes quality more profitable for it than for its rivals. The rivals choose internal qualities that are lower than the quality of their interconnections with the monopolist because connection with the monopolists' network provides more value to their customers than do their own networks. For the same reason, the rivals choose higher interconnection qualities with the monopolist than with each other.

5. New Competitive Entry into a Formerly Monopoly Market

In this section, I examine a new entry setting, a situation where firms 2 and 3 enter market *A*. Because firm 1 is an incumbent, it has a cost advantage of c_0 in *A* and has the ability to raise its rivals' costs.

Lemma 3 shows that interconnecting firms choose the same external quality if the incumbent does not raise its rivals' interconnection costs.

Lemma 3. If $r_\theta = 0$ in the new entry setting, then all firms implement the same external quality for the same interconnection; i.e., $\theta^*_{i,j} = \theta^*_{j,i}$ for $j \neq i$, for all $i, j = 1, 2, 3$.

Proposition 3 provides this sections main findings.

Proposition 3. In the new entry setting, the incumbent will raise the entrants' quantity costs. However, it will not raise the entrants' interconnection costs. That is to say, $r_q^* > 0$ and $r_\theta^* = 0$.

The incumbent chooses to raise its rivals' quantity costs because raising these costs causes the rivals to reduce their quantities, which allows the incumbent to increase its output and its profits. However, the incumbent will never raise its rivals' interconnection costs because raising these costs would cause the rivals to implement lower external quality than the level preferred by the incumbent.

In some countries, incumbents have restricted interconnection capacity for rivals. This restriction causes calls or messages between the rival networks to be delayed, dropped, or not completed. This would appear to be in conflict with the conclusion that an incumbent would not raise its rivals' interconnection costs nor strategically degrade interconnection quality. But field interviews with customers revealed that customers generally did not understand network interconnection and believed that the service problem was caused by the rivals' failing to provide adequate internal quality. This perception lowered the demand for the rivals' services, which caused rivals to incur extra costs to obtain and keep customers. Therefore, even though the incumbents' choices related to interconnection, the effect was to raise its rivals' quantity costs.

Corollary 2 further describes the firms' quantity choices and quality choices.

Corollary 2. In the new entry setting:

a. The incumbent chooses higher quantities than does each of its rivals;

b. The incumbent implements an internal quality that exceeds its external quality;

c. The rivals implement the same external quality when connecting with the incumbent as the incumbent chooses;

d. The rivals implement internal quality that is equal to the external quality that they implement for interconnecting with each other; and

e. The rivals' implement internal quality that is lower than the external quality that they implement for interconnecting with the incumbent.

That is to say, $\sum_{\mu=A}^{B}\left(q_{1,\mu}^{*}\left(q_{j,A},q_{j,B}\right)-q_{j,\mu}^{*}\left(q_{1,A},q_{1,B}\right)\right)>0$ and $\theta_{1,1}^{*}>\theta_{1,j}^{*}=\theta_{j,1}^{*}>\theta_{j,j}^{*}=\theta_{j,k}^{*}$ for $j \neq k$, for all j, k = 2, 3.

The incumbent chooses higher quantities because it has a cost advantage, and its higher quantity choices drive its higher quality choices. As in previous cases, firms that are interconnecting make equal external quality choices when interconnecting, so no firm prefers a higher or lower interconnection quality than the other firm prefers.

Corollary 3. In the new entry setting, the entrants' quantity choice in market i is a strategic substitute for the incumbent's quantity choice in market j, for all $i \neq j$ and $i, j = A, B$. However, the incumbent's quantity choice market i is a strategic complement to the entrants' quantity choice in market j.

The incumbent and entrants have opposite responses to each other's other-market production because the incumbent's higher internal quality causes it to have a greater response to its internalized network externalities. A firm internalizes more network externalities when it serves two markets than when it serves only one market. Furthermore, higher internal quality internalizes more network externalities than does a lower internal quality. As a result, when a larger firm connects with a smaller firm and both firms serve two markets, the larger firm quantity choice in the first market affects its quantity choice in the second market more than does the smaller rival's quantity choice in the first market. Conversely, the larger firm's quantity choice in the first market affects the smaller firm's quantity choice in the second market more than does the smaller firm's own quantity choice in the first market. These opposite reactions result from the firms' quality choices. The larger firm implements a higher internal quality than it does external quality for interconnecting with the smaller firm. Therefore, the larger firm's quantity choice has a greater feedback effect than does the smaller firm's quantity choice. Conversely, the smaller firm implements an internal quality that is lower than its external quality with the larger firm. Therefore, the larger firm's quantity choice has a greater affect on the smaller firm's quantity choice.

For example, assume the entrants' increase their quantity in market *A*. This higher quality causes the incumbent to choose a lower quantity in market *A* because the entrants' quantity choice is a strategic substitute for the incumbent's market-*A* quantity. With respect to the incumbent's quantity choice in market *B*, the entrants' higher quantity in market *A* has a direct positive effect on the incumbent's quantity choice in market *B*. However, this direct effect is weaker than the indirect effect, which is caused by the incumbent lowering its market-*B* quantity because of its lower market-*A* quantity. Just the opposite happens for the entrants. Assume that the incumbent unilaterally chooses a higher quantity in market *A*. In response, the entrants' lower their quantity choice in market *A*. Their lower quantity choice in market *A* lowers the positive network externalities that result from their serving both markets. However, their internal quality is lower than their external quality with the incumbent. Therefore, the positive network externality caused by the incumbent's higher quantity choice in market *A* is greater than the effect of the entrants' lower quantity choice in market *A*. As a result, they have a higher quantity choice in market *B*.

6. Conclusion

In this paper, I examine incentives for discrimination in network interconnection. I find that a large firm implements the same external quality for a given network interconnection as does its smaller rival. Furthermore, I find that smaller firms offer their own customers an internal network quality that is lower than the interconnection quality that the smaller firms implement with the larger firm.

My results conflict with the findings of Crémer et al. (1999). Their model assumes that differences in firm size result from differences in numbers of attached customers, and find that these differences in attached customers cause firms with a higher number of attached customers to prefer a lower quality interconnection than a firm with a lower number of attached customers. They obtain this result because firms ignore the preferences of their own attached customers when choosing interconnection quality, but take into account unattached customers' preferences. The assumption that attached customers have entered into contracts that do not reflect the firm's quality choices, but that unattached customers' contracts do reflect the firm's quality choices, seems difficult to support. If it were optimal for firms to ignore preferences of captive customers, such as when the customers were in a monopoly market, then the monopoly in my model would have done so. That the monopoly in my model did not ignore its captive customers' preferences indicates that it is not optimal for firms to enter into contracts in which customers believe the firms will ignore their preferences when making quality choices. Therefore, these customers are not attached in the sense of Crémer et al. (1999). Because it is difficult to construct a scenario in which customers and firms choose contracts that result in attached customers in the sense of Crémer et al. (1999), I assume that asymmetry in firm size results from access to monopoly markets and cost asymmetries.

This paper indicates that the EU may not have been justified in its conclusion that a larger Internet firm resulting from the MCI-WorldCom merger or the WorldCom-Sprint merger would discriminate against European firms for access to the Internet backbone. It appears true that the larger firm would provide its own customers with a higher quality service than it would provide its competitors, but the larger firm's interconnection quality choice would be no different than the smaller firms' interconnection quality choice for connecting with the larger firm. Furthermore, the interconnection quality the larger firm would choose for connecting with the smaller firms would be higher than the quality the smaller firms would choose for connecting with each other.

Appendix

Lemma A1. Profit maximizing behavior for choices of external quality results in a set of Nash equilibria $\theta_{i,j} = \theta_{j,i} \in [0, min\ \{\theta^*_{i,j}, \theta^*_{j,i}\}]$, where $\theta^*_{i,j}$ represents *i*'s profit maximizing choice for external quality with *j*'s network if *i* were allowed to dictate the quality, and $\theta^*_{j,i}$ represents *j*'s profit maximizing choice for external quality with *i*'s network if *j* were allowed to dictate external quality.

Proof: Recall that the firm with the lowest quality choice determines the effective quality of the interconnection. Now consider strategy choices that have unequal quality for communications established by *i*'s customers. The firm with the higher quality can decrease its costs and not affect revenues by choosing a lower quality, so all unequal capacity choices are not Nash equilibria. Now consider the choices $0 \leq \theta_{i,j} = \theta_{j,i} \leq min\ \{\theta^*_{i,j}, \theta^*_{j,i}\}$. Neither firm would increase its quality because it would incur costs and gain no revenues. Neither firm would decrease its quality because, at a lower quality, its marginal revenue from quality would be greater than its marginal cost of quality. Therefore, all of these choices are Nash equilibria. Now consider the choices $\theta_{i,j} = \theta_{j,i} > min\ \{\theta^*_{i,j}, \theta^*_{j,i}\}$. For at least one of the firms, marginal revenue from the quality choice is less than the quality choice's marginal cost of quality, so this firm can improve its profits by decreasing its quality. Therefore, equal quality choices in this range are never a Nash equilibrium.

Proof of Lemma 1. Assume that Lemma 1 is false. Then at equilibrium, for some *i*, *j* = 1, 2, 3 and $i \neq j$, $\tau + s_{i,\mu} - p_{i,\mu} > \tau + s_{j,\mu} - p_{j,\mu} \Leftrightarrow s_{i,\mu} - p_{i,\mu} > s_{j,\mu} - p_{j,\mu}$, which means that customers would strictly prefer network *i* over network *j*. This conflicts with the assumption that customers buy from both networks in equilibrium, so Lemma 1 must be true.

Proof of Proposition 1. Because there is no incumbent firm, r_q = 0 and r_θ = 0. From (7), the first order conditions for an internal solution include:

$$\frac{\partial \pi_i}{\partial q_{i,B}} = \bar{\tau} - c - 2(1 - v\theta_{i,i})q_{i,B} - \sum_{j \neq i, j=2}^{4} (1 - v\theta_{i,j})q_{j,B} = 0,$$

$$\frac{\partial \pi_i}{\partial \theta_{i,i}} = vq_{i,B}^2 - K_\theta(\theta_{1,1}) = 0 \text{, and} \tag{A1}$$

$$\frac{\partial \pi_i}{\partial \theta_{i,j}} = vq_{i,B}q_{j,B} - K_\theta(\theta_{i,j}) = 0. \tag{A2}$$

From (A1), $K_\theta(\theta_{i,i}^*) = v(q_{i,B}^*)^2$, or $\theta_{i,i}^* = K_\theta^{-1}\left(v(q_{i,B}^*)^2\right)$. From (A2), $K_\theta(\theta_{i,j}^*) = K_\theta(\theta_{j,i}^*) = vq_{i,B}^* q_{j,B}^*$, or $\theta_{i,j}^* = \theta_{j,i}^* = K_\theta^{-1}(vq_{i,B}^* q_{j,B}^*)$. Because the equilibrium is symmetric, $q_{i,B}^* = q_{j,B}^*$. Therefore, $\theta_{i,i}^* = \theta_{j,j}^* = \theta_{i,j}^* = \theta_{j,i}^*$ for $i \neq j$ and i, j = 2, 3, 4. This confirms Proposition 1.

Proof of Proposition 2. Because firm 1 is not competing against entrants in its monopoly market, it cannot increase its rivals' costs. From (6), firm 1's first order conditions for an internal solution include:

$$\frac{\partial \pi_1}{\partial q_{1,A}} = \bar{\tau} - c - 2(1 - v\theta_{1,1})q_{1,A} + 2v\theta_{1,1}q_{1,B} + v\sum_{j=2}^{3} \theta_{1,j}q_{1,j} = 0,$$

$$\frac{\partial \pi_1}{\partial q_{1,B}} = \bar{\tau} - c - \sum_{j=2}^{3} (1 - v\theta_{1,j})q_{j,B} - 2(1 - v\theta_{1,1})q_{1,B} + 2v\theta_{1,1}q_{1,A} = 0, \tag{A3}$$

$$\frac{\partial \pi_1}{\partial \theta_{1,1}} = vq_{1,A}^2 + 2vq_{1,A}q_{1,B} + vq_{1,B}^2 - K_\theta(\theta_{1,1}) = 0 \text{, and} \tag{A4}$$

$$\frac{\partial \pi_1}{\partial \theta_{1,j}} = vq_{2,B}\left(q_{1,A} + q_{1,B}\right) - K_\theta\left(\theta_{1,j}\right) = 0 . \qquad \text{(A5)}$$

First order conditions for an internal solution for firm $j \neq 1$ include:

$$\frac{\partial \pi_j}{\partial q_{j,B}} = \overline{\tau} - c - \sum_{i \neq j}^{3}\left(1 - v\theta_{j,i}\right)q_{i,B} - 2\left(1 - v\theta_{j,j}\right)q_{j,B} + 2v\theta_{j,1}q_{1,A} = 0 , \qquad \text{(A6)}$$

$$\frac{\partial \pi_j}{\partial \theta_{j,j}} = vq_{j,B}^2 - K_\theta\left(\theta_{j,j}\right) = 0 , \qquad \text{(A7)}$$

$$\frac{\partial \pi_j}{\partial \theta_{j,i}} = vq_{j,B}q_{i,B} - K_\theta\left(\theta_{j,i}\right) = 0 \quad \text{for } i \neq j \text{ , and} \qquad \text{(A8)}$$

$$\frac{\partial \pi_j}{\partial \theta_{j,1}} = vq_{j,B}\left(q_{1,A} + q_{1,B}\right) - K_\theta\left(\theta_{j,1}\right) = 0 . \qquad \text{(A9)}$$

From (A5), $K_\theta\left(\theta_{1,j}^*\right) = vq_{2,B}^*\left(q_{1,A}^* + q_{1,B}^*\right)$, or $\theta_{1,j}^* = K_\theta^{-1}\left(vq_{2,B}^*\left(q_{1,A}^* + q_{1,B}^*\right)\right)$. From (A9), $K_\theta\left(\theta_{j,1}^*\right) = vq_{2,B}^*\left(q_{1,A}^* + q_{1,B}^*\right)$, or $\theta_{j,1}^* = K_\theta^{-1}\left(vq_{2,B}^*\left(q_{1,A}^* + q_{1,B}^*\right)\right)$. Therefore, $\theta_{1,j}^* = \theta_{j,1}^*$ for j = 2, 3. Now consider the external quality choices for the interconnection between firms 2 and 3. From (A8), $\theta_{2,3}^* = \theta_{3,2}^* = K_\theta^{-1}\left(vq_{2,B}^*q_{3,B}^*\right)$. This confirms Proposition 2.

Proof of Corollary 1 and Lemma 2: Because I assume a symmetric equilibrium for firms 2 and 3, (A7) and (A8) imply $K_\theta^{-1}\left(vq_{2,B}^*q_{3,B}^*\right) = K_\theta^{-1}\left(v\left(q_{2,B}^*\right)^2\right) = K_\theta^{-1}\left(v\left(q_{3,B}^*\right)^2\right)$, which implies that $\theta_{2,3}^* = \theta_{3,2}^* = \theta_{2,2}^* = \theta_{3,3}^*$.

Now consider quality choices for interconnection between asymmetric networks. Solving (A3) for $q_{1,B}$ in terms of $q_{1,A}$, and solving (A6) for $q_{j,B}$ in terms of $q_{1,A}$ gives:

$$q^*_{1,B} = \frac{(\bar{\tau} - c)\left[3\left(1 - v\theta^*_{j,j}\right) - 2\left(1 - v\theta^*_{1,j}\right)\right] + q^*_{1,A}\left[6v\theta^*_{1,1}\left(1 - v\theta^*_{j,j}\right) - 2v\theta^*_{1,j}\left(1 - v\theta^*_{1,j}\right)\right]}{6\left(1 - v\theta^*_{1,1}\right)\left(1 - v\theta^*_{j,j}\right) - 2\left(1 - v\theta^*_{1,j}\right)^2} \quad \text{(A10)}$$

and

$$q^*_{j,B} = \frac{(\bar{\tau} - c)\left[2\left(1 - v\theta^*_{1,1}\right) - \left(1 - v\theta^*_{1,j}\right)\right] + q^*_{1,A}\left[2v\theta^*_{1,j}\left(1 - v\theta^*_{1,1}\right) - 2v\theta^*_{1,1}\left(1 - v\theta^*_{1,j}\right)\right]}{6\left(1 - v\theta^*_{1,1}\right)\left(1 - v\theta^*_{j,j}\right) - 2\left(1 - v\theta^*_{1,j}\right)^2}. \quad \text{(A11)}$$

Consider how changes in the cost of quality affect the optimal quantity choices in (A10) and (A11). For simplicity, assume for purposes of this proof that cost functions for quality are such that corner solutions are obtained for quality. If the cost of quality is sufficiently low that firms choose the corner solution $\theta^*_{i,j} = 1$, then the monopolist chooses a greater quantity than its rival in market *B*; i.e.,

$$q^*_{1,B} = \frac{t - c}{4(1 - v)} + \frac{v}{1 - v} q^*_{1,A} > \frac{t - c}{4(1 - v)} = q^*_{j,B}. \quad \text{(A12)}$$

As the cost of quality becomes higher for every level of quality, firms lower their quality choices. The rivals lower their internal quality and their external quality with each other before they lower their external quality choices with the monopolist and before the monopolist lowers its quality choices. To demonstrate this result, note that at the corner solution where quality is equal to 1,

$$v\left(q^*_{1,A} + q^*_{1,B}\right)^2 > vq^*_{j,B}\left(q^*_{1,A} + q^*_{1,B}\right) > vq^*_{j,B}q^*_{k,B} = v\left(q^*_{i,B}\right)^2 \quad \text{(A13)}$$

for $j \neq k$, and $i, j, k = 2, 3$. Combining (A13) with (A4), (A5), (A7) through (A9), and (A12), gives,

$$K_\theta^{-1}\left(v\left(q^*_{1,A} + q^*_{1,B}\right)^2\right) \geq K_\theta^{-1}\left(vq^*_{j,B}\left(q^*_{1,A} + q^*_{1,B}\right)\right) \geq K_\theta^{-1}\left(vq^*_{j,B}q^*_{k,B}\right) = K_\theta^{-1}\left(v\left(q^*_{i,B}\right)^2\right). \quad \text{(A14)}$$

(A14) contains weak inequalities because the maximum value for quality is 1.

Because $K_\theta^{-1}\left(vq^*_{j,B}q^*_{k,B}\right)$ and $K_\theta^{-1}\left(v\left(q^*_{i,B}\right)^2\right)$ are the lowest values in (A3), $\theta^*_{j,k}, \theta^*_{j,j}, \text{and}\, \theta^*_{k,k}$ are the first to move below the corner solution $\theta^*_{i,j} = 1$ as the cost of quality increases for each quality choice. $\theta^*_{1,j}$ and $\theta^*_{1,k}$ decrease next as the cost of quality choices increases because $K_\theta^{-1}\left(vq^*_{j,B}\left(q^*_{1,A}+q^*_{1,B}\right)\right)$ is the next lowest value in (A3). $\theta^*_{1,1}$ is the last quality choice to decrease. Because $\theta^*_{1,1} > \theta^*_{1,j} > \theta^*_{j,k} = \theta^*_{j,j}$ for all $j, k = 2, 3$, $q^*_{1,B} > q^*_{j,B} = q^*_{k,B}$ for all levels of cost of quality. These quantity choices cause the pattern of quality choices to persist until costs are so high that the corner solution $\theta^*_{i,j} = 0$ is reached, at which point $q^*_{1,B} = q^*_{2,B} = q^*_{3,B} = \dfrac{\bar{\tau} - c}{4}$. This confirms Corollary 1 and Lemma 2.

Proof of Lemma 3: The incumbent's first order conditions for an internal solution include:

$$\frac{\partial \pi_1}{\partial q_{1,A}} = \bar{\tau} - c - \sum_{j=2}^{3}\left(\left(1 - v\theta_{1,j}\right)q_{j,A} + v\theta_{1,j}q_{j,B}\right) - 2\left(1 - v\theta_{1,1}\right)q_{1,A} + 2v\theta_{1,1}q_{1,B} = 0, \quad \text{(A15)}$$

$$\frac{\partial \pi_1}{\partial q_{1,B}} = \bar{\tau} - c - \sum_{j=2}^{3}\left(\left(1 - v\theta_{1,j}\right)q_{j,B} + v\theta_{1,j}q_{j,A}\right) - 2\left(1 - v\theta_{1,1}\right)q_{1,B} + 2v\theta_{1,1}q_{1,A} = 0, \quad \text{(A16)}$$

$$\frac{\partial \pi_1}{\partial \theta_{1,1}} = v\left(q_{1,A} + q_{1,B}\right)^2 - K_\theta\left(\theta_{1,1}\right) = 0, \text{ and}$$

$$\frac{\partial \pi_1}{\partial \theta_{1,j}} = v\left(q_{1,A} + q_{1,B}\right)\left(q_{j,A} + q_{j,B}\right) - K_\theta\left(\theta_{1,j}\right) = 0. \quad \text{(A17)}$$

First order conditions for an internal solution for entrant $j \neq 1$ include:

$$\frac{\partial \pi_j}{\partial q_{j,A}} = \bar{\tau} - c - c_0 - r_q - \sum_{k \neq j}^{3} \left(\left(1 - v\theta_{j,k}\right) q_{k,A} + v\theta_{j,k} q_{k,B} \right) - 2\left(1 - v\theta_{j,j}\right) q_{j,A} \quad , \tag{A18}$$
$$+ 2v\theta_{j,j} q_{j,B} = 0$$

$$\frac{\partial \pi_j}{\partial q_{j,B}} = \bar{\tau} - c - \sum_{k \neq j}^{3} \left(\left(1 - v\theta_{j,k}\right) q_{k,B} + v\theta_{j,k} q_{k,A} \right) - 2\left(1 - v\theta_{j,j}\right) q_{j,B} + 2v\theta_{j,j} q_{j,A} = 0 \, , \tag{A19}$$

$$\frac{\partial \pi_j}{\partial \theta_{j,j}} = v\left(q_{j,A} + q_{j,B}\right)^2 - K_\theta\left(\theta_{j,j}\right) = 0 \, ,$$

$$\frac{\partial \pi_j}{\partial \theta_{j,k}} = v\left(q_{j,A} + q_{j,B}\right)\left(q_{k,A} + q_{k,B}\right) - K_\theta\left(\theta_{j,k}\right) = 0 \, , \text{ for } j \neq k, \text{ and} \tag{A20}$$

$$\frac{\partial \pi_j}{\partial \theta_{j,1}} = v\left(q_{1,A} + q_{1,B}\right)\left(q_{j,A} + q_{j,B}\right) - K_\theta\left(\theta_{j,1}, r_\theta\right) = 0 \, . \tag{A21}$$

Consider (A17), (A20), and (A21). Recalling that $K(\theta_{i,j},0) = K(\theta_{i,j})$, the proof of Proposition 2 confirms Lemma 3.

Proof of Proposition 3: First consider the incumbent's optimal choice of r_θ. If $r_\theta > 0$, then $\theta^*_{1,j} > \theta^*_{j,1} \ \forall \ j \neq 1$. Because the firm with the lowest external quality preference determines the effective interconnection quality, the interconnection quality between the incumbent and the entrants is lower than the incumbent's optimal external quality choice. Therefore, the incumbent's optimal choice for r_θ is $r_\theta^* = 0$.

Now consider firm 1's optimal choice of r. Combining (A15) and (A16) gives:

$$q^*_{1,A}\left(q_{j,A}, q_{j,B}\right) = \frac{\bar{\tau} - c}{2\left(1 - 2v\theta^*_{1,1}\right)} - \frac{2\left(1 - v\theta^*_{1,1} - v\theta^*_{1,j}\right)}{2\left(1 - 2v\theta^*_{1,1}\right)} q_{j,A} - \frac{2\left(v\theta^*_{1,1} - v\theta^*_{1,j}\right)}{2\left(1 - 2v\theta^*_{1,1}\right)} q_{j,B} \, , \text{ and} \tag{A22}$$

$$q^*_{1,B}\left(q_{j,A}, q_{j,B}\right) = \frac{\bar{\tau} - c}{2\left(1 - 2v\theta^*_{1,1}\right)} - \frac{2\left(1 - v\theta^*_{1,1} - v\theta^*_{1,j}\right)}{2\left(1 - 2v\theta^*_{1,1}\right)} q_{j,B} - \frac{2\left(v\theta^*_{1,1} - v\theta^*_{1,j}\right)}{2\left(1 - 2v\theta^*_{1,1}\right)} q_{j,A} \, . \tag{A23}$$

Similar calculations for (A18) and (A19) give:

$$q^*_{j,A}\left(q_{1,A},q_{1,B}\right)=\frac{\bar{\tau}-c-\left(1-v\theta^*_{j,j}\right)\left(c_0+r_q\right)-\left(1-v\theta^*_{j,j}-v\theta^*_{j,1}\right)q_{1,A}+\left(v\theta^*_{j,1}-v\theta^*_{j,j}\right)q_{1,B}}{3\left(1-2v\theta^*_{j,j}\right)}, \text{(A24)}$$

and

$$q^*_{j,B}\left(q_{1,A},q_{1,B}\right)=\frac{\bar{\tau}-c-v\theta^*_{j,j}\left(c_0+r_q\right)-\left(1-v\theta^*_{j,j}-v\theta^*_{j,1}\right)q_{1,B}+\left(v\theta^*_{j,1}-v\theta^*_{j,j}\right)q_{1,A}}{3\left(1-2v\theta^*_{j,j}\right)}. \text{(A25)}$$

Let $N_j\equiv 2\left[\left(1-v\theta^*_{j,j}-v\theta^*_{j,1}\right)\left(v\theta^*_{j,1}-v\theta^*_{1,1}\right)+\left(1-v\theta^*_{1,1}-v\theta^*_{j,1}\right)\left(v\theta^*_{j,1}-v\theta^*_{j,j}\right)\right]$ and

$D_j\equiv 6\left(1-2v\theta^*_{j,j}\right)\left(1-2v\theta^*_{1,1}\right)-2\left[\left(1-v\theta^*_{j,j}-v\theta^*_{j,1}\right)\left(1-v\theta^*_{1,1}-v\theta^*_{j,1}\right)+\right.$

$\left.\left(v\theta^*_{j,1}-v\theta^*_{1,1}\right)\left(v\theta^*_{j,1}-v\theta^*_{j,j}\right)\right]$. Substituting (A22) and (A23) into (A24) and (A25)

gives:

$$q^*_{j,A}=\frac{\left(1-4v\theta^*_{1,1}+v\theta^*_{1,j}\right)\left(D_j-N_j\right)\left(\bar{\tau}-c\right)-2\left[D_j-\left(D_j-N_j\right)v\theta^*_{j,j}\left(1-2v\theta^*_{1,1}\right)\right]\left(c_0+r_q\right)}{D_j^2-N_j^2}, \text{(A26)}$$

and

$$q^*_{j,B}=\frac{\left(1-4v\theta^*_{1,1}+v\theta^*_{1,j}\right)\left(D_j-N_j\right)\left(\bar{\tau}-c\right)-2\left[N_j-\left(N_j-D_j\right)v\theta^*_{j,j}\left(1-2v\theta^*_{1,1}\right)\right]\left(c_0+r_q\right)}{D_j^2-N_j^2}. \text{(A27)}$$

Substituting (A26) and (A27) into (6) and differentiating with respect to r_q gives the incumbent's first order condition for an internal solution for choosing r_q in the first stage of the game, namely:

$$\frac{\partial\pi_1\left(q^*_{1,A},q^*_{1,B},q^*_{j,A},q^*_{j,B},\boldsymbol{\theta}^*_1,\boldsymbol{\theta}^*_j\right)}{\partial r_q}=\frac{2\left(1-v\theta^*_{1,j}\right)}{D_j-N_j}-\chi_r\left(r_q\right)=0.$$

The incumbent's optimal choice for r_q is $r^*_q\equiv\chi_r^{-1}\left(\frac{2\left(1-v\theta^*_{1,j}\right)}{D_j-N_j}\right)>0$. This confirms

Proposition 3.

Proof of Corollary 2: The rivals' higher costs cause each to choose lower quantity than the incumbent. Recalling that firms 2 and 3 make symmetric choices in equilibrium, the proof to Corollary 1 confirms $\theta^*_{1,1} > \theta^*_{1,j} > \theta^*_{j,j} = \theta^*_{j,k}$ for $j \neq k$ for all j, k = 2, 3. This confirms Corollary 2.

Proof of Corollary 3: Consider (A23). An increase in the entrants' quantity choice in market *A* decreases the incumbent's quantity choice in market *B* because $\theta^*_{1,1} > \theta^*_{1,j}$ for all j = 2, 3. Analysis of (A22) shows that the same holds for the entrants' quantity choice in market *B* and the incumbent's quantity choice in market *A*. Now consider the entrants' response to the incumbent. From (A24), the entrants' increase their quantity choice in market *A* if the incumbent increases its quantity choice in market *B* because $\theta^*_{1,j} > \theta^*_{j,j}$ for all j = 2, 3. Analysis of (A25) shows that the same holds for the incumbent's quantity choice in market *B* and the entrant's quantity choice in market *A*. This confirms Corollary 3.

Bibliography

Broadview. (1998) *Technology M&A Report: First Half 1998* http://www.broadview.com/info/na_ma98fh.html#here.

Capron, Laurence, and Will Mitchell. (1997) "Outcomes of International Telecommunications Acquisitions: Analysis of Four Cases with Implications for Acquisitions Theory," *European Management Journal* 15: 237-251.

Crémer Jacques, Patrick Rey, and Jean Tirole. (1999) "Connectivity in the Commercial Internet," Working paper 87, University of Toulouse.

Economides, Nicholas. (1998) "The Incentive for Non-Price Discrimination by an Input Monopolist," *International Journal of Industrial Organization* 16: 271-284.

Galbi, Douglas and Chris Keating. (February 1996) "Global Communication Alliances: Forms and Characterizations of Emerging Organizations." Report of the International Bureau of the Federal Communications Commission (unpublished).

Global One. (1996) "Global One, International Joint Venture of Deutsche Telekom, France Telecom, and Sprint, Begins Operations," Press Release, January 31, 1996.

Jamison, Mark A. (1998) "Emerging Patterns in Global Telecommunications Mergers and Alliances," *Industrial and Corporate Change* 7(4): 695-713.

Jamison, Mark A. (1999a) "Business Imperatives," in *The New Global Telecommunications Industry & Consumers* Jorge R. Schement, ed., Penn State Institute for Information Policy: University Park, Pennsylvania, pp. 19-30.

Jamison, Mark A. (1999b) " Impacts of Mergers and Global Rivalry on Local Network Competition," Presented at the *Telecommunications Policy Research Conference*, September 26, 1999.

Jamison, Mark A. (2000) "The Effects of Double Feedback on Incentives for Cross-Border Mergers in Network Industries," unpublished working paper.

Jasinski, Piotr. (1997) "Competition Rules and Regulations in Telecommunications: The Case of Poland's Intent to Join the EU." In D. J. Ryan, editor, *Privatization and Competition in Telecommunications*, Westport, Connecticut: Praeger. pp. 127-148.

Kennard, William E. (1999) Letter to Mr. Richard C. Notebaert, Chairman and Chief Executive Officer of Ameritech Corporation, and to Mr. Edward E. Whitacre, Jr., Chairman and Chief Executive Officer of SBC Communications, Inc., April 1, 1999.

Mandy, David M. and David E. M. Sappington. (June 2000) "Incentives for Sabotage in Vertically-Related Industries," (unpublished).

McDavid, Janet L. (1997) "Antitrust Issues in Communications Industries," in *Competitive Policy in Communications Industries: New Antitrust Approaches* J. Sims and P. L. Verveer, eds., Glasser LegalWorks: Little Falls, New Jersey, pp. 43-49.

Olbeter, Erik R., and Matt Robison. (1999) *Breaking the Backbone: The Impact of Regulation on Internet Infrastructure Deployment* (unpublished).

US Department of Commerce and US Department of Agriculture. (2000) *Advanced Telecommunications in Rural America: The Challenge of Bringing Broadband Services to All Americans*, Washington, D.C.

Weisman, Dennis L. (1999) "Footprints in Cyberspace: Toward a Theory of Mergers in Network Industries," *info* 1(4): 367-369.