Market Concentration and Incentives to Discriminate Against Rivals in Network Industries

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Mark A. Jamison*
Director of Telecommunications Studies
Public Utility Research Center
And Associate Director for Economic and Business Studies
Center for International Business Education and Research
Warrington College of Business Administration
University of Florida
jamisoma@ufl.edu
+1.352.392.2929

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Mark A. Jamison
University of Florida

Abstract

I examine the effects of market concentration on interconnection in network industries. Using Cournot interactions, each network simultaneously chooses quantity, quality for communications within the provider's own network (internal quality), and quality for communications between the provider's network and other networks (external quality). I find that larger networks do not discriminate against smaller networks. Larger networks choose higher internal quality than do smaller networks. Large networks and small networks choose identical external quality when interconnecting with each other. 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. Recent examples of large mergers include the merger of Bell Atlantic with NYNEX in 1997, and then with GTE in 2000 to form Verizon; SBC's acquisition of Pacific Telesis in 1997, Southern New England Telephone in 1998, and Ameritech in 1999; WorldCom's purchase of MCI in 1998; Vodafone's acquisition of AirTouch in 1999 and Mannesmann in 2000; and the merger of AOL and Time Warner in 2001.

Competition regulators, utility regulators, and others often raise concerns that these mergers might increase market dominance and that the merged companies might hinder competition. Concerned with market dominance in the Internet, the European Union (EU) required MCI and WorldCom to divest a portion of their Internet business as a condition of approving WorldCom's purchase of MCI (Crémer et al., 2000, and Ungerer, 2000) and halted WorldCom's planned purchase of Sprint. As a precondition for approving the AOL Timer Warner merger, the US Federal Communications Commission (FCC) required AOL Time Warner to open its cable systems to competitor Internet Service Providers (ISPs) and to interconnect its Instant Messaging software with that of rivals before introducing advanced Instant Messaging-based services on its cable systems.[1] Economides (1998) finds that an incumbent network provider has an incentive to raise rivals' costs. 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

[1] The FCC did allow AOL Time Warner the opportunity to obtain relief from the Instant-Messaging requirement by showing clear and convincing evidence that the requirement no longer served the public interest.

Internet. Crémer et al. (2000) find that larger Internet firms have an incentive to lower the quality of their interconnection with smaller rivals. 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. Also, Kende (2000) concludes that there are no anti-competitive actions on the part of any Internet backbone providers with respect to their interconnection agreements.

This paper extends this research by examining the effects of market concentration on incentives to discriminate in network interconnection. I examine an oligopoly model in which customers initially form expectations regarding network quality and size, then firms simultaneously choose output, network quality for internal communications (which I call internal quality), and interconnection quality for communications between networks (which I call external quality). Lastly, customers choose their network providers.[2] My model differs from traditional network industry models in that firms simultaneously choose output and quality. The typical sequence is for firms to make credible commitments for interconnection quality before choosing output. This sequence is probably appropriate for networks of fax machines and computer components, where the product design determines compatibility with rivals' products. However, software determines interconnection quality in Instant Messaging and in some aspects of the Internet. Firms' choices regarding network maintenance and circuits[3] also determine

[2] I limit my analysis to situations where equilibria exist by considering only customer expectations of output and quality that are equal to actual output and quality in equilibrium. (Katz and Shapiro, 1985)

[3] Physical telecommunications networks interconnect through physical circuits. Variations in the quality of manufacturer equipment can cause circuits to vary in the quality of their transmission of telecommunications signals. A firm can discriminate against rivals by choosing to interconnect using circuits that provide below-average transmission quality.

interconnection quality in the Internet. Because firms can change software and their choices of circuits for interconnection while providing output to customers, it seems reasonable to assume that these quality choices are made simultaneously with output.

To examine firms' incentives to discriminate in interconnection, I consider three potential sources of market dominance: monopoly power, incumbency, and the ability to raise rivals' costs. I first examine whether a firm with a monopoly in one market would discriminate against rivals in a second market. I find that networks choose lower external quality when connecting with a smaller network than when connecting with larger networks because firms base their quality choices on network size, customer value of interconnection, and the cost of interconnection. The monopoly chooses higher internal quality than external quality. In contrast to Crémer et al. (2000), the monopoly does not discriminate because it and its rivals choose the same external quality when interconnecting with each other. The rivals choose lower internal quality than external quality when interconnecting with firms with larger networks. I next examine whether a large, incumbent network provider would discriminate against smaller rivals. I apply an oligopoly model in which firms have identical cost structures for quality, but not necessarily for output. 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. As in the monopoly case, this does not result in discrimination because larger networks and smaller networks choose the same external quality when interconnecting with each other.

Lastly, I examine whether incumbent operators have an incentive to raise rivals' costs. An incumbent can raise its rivals' costs, for example, by delaying access to essential facilities. I apply a four-stage game in which an incumbent chooses whether to sabotage rivals in the first stage after customers form their expectations. Firms compete for customers and seek to maximize their individual profits in the third stage by simultaneously choosing quantity, internal quality, and external quality. Customers make their purchasing decisions in the last stage. I find that incumbent firms will raise entrants' quantity costs, but will never sabotage rivals by raising the rivals' costs of interconnection.

The analysis proceeds as follows. Section 2 describes the model. Section 3 presents a benchmark case in which three identical firms compete in a single market. Section 4 presents the case in which one of the firms is 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 the models developed by Katz and Shapiro (1985) and Crémer et al. (2000) in which customers initially form expectations about network size and quality, then firms play a quality and quantity game and determine prices taking customer expectations as given, and lastly customers choose network providers based on prices and the value customers place on network services. 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.[4] Customers desire to communicate with customers in both markets, so $s_{i,\mu}$ is given by

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

I let $v \in (0, 1/4)$ represent 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. (2000) 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 connect networks across markets, $s_{i,\mu}$ for customers in one market is increasing in quantity for both markets. Let $\theta_{i,i} \in [0, 1]$ be firm *i*'s internal quality choice and $\theta_{i,j} \in [0, 1]$ be 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

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

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.[5]

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, AOL Time Warner offers proprietary content and functions for its own Internet customers and not for users of other ISPs. 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, 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.

[5] 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.

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

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

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 $\tau = \overline{p}_{\mu}$. 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 $\overline{p}_{\mu}$. 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

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

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 by 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 FCC recently fined GTE \$2.7 million for allegations that GTE denied rivals access to GTE facilities for locating equipment.[6] 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,

[6] This occurred before GTE and Bell Atlantic merged to form Verizon.

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.[7] 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 cost of serving $q_{1,A} + q_{1,B}$ customers with quality choices $\theta_1 = \{\theta_{1,1}, \theta_{1,2}, \theta_{1,3}\}$ is

$$C\left(q_{1,A}, q_{1,B}, \theta_1\right) = c\left(q_{1,A} + q_{1,B}\right) + \sum_{j=2}^{3} K\left(\theta_{1,j}\right) + K\left(\theta_{1,1}\right) + \chi(r_q) + \phi(r_\theta)\,, \tag{5}$$

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

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

I assume a sequential 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

[7] 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.

quality levels. Therefore, (4) and (5) imply that firm 1's profit maximization problem can be written as:

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

$$\begin{aligned}
\text{subject to} \quad & \theta_{1,j} \in [0,1] \quad \text{for } j = 1,\ldots,3 \\
& r_q, r_\theta \geq 0 \\
& q_{1,\mu} \geq 0 \qquad \text{for } \mu = A, B.
\end{aligned}$$

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

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

$$\begin{aligned}
\text{subject to} \quad & \theta_{j,k} \in [0,1] \quad \text{for } k = 1,2,3 \\
& q_{j,\mu} \geq 0 \qquad \text{for } \mu = A, B.
\end{aligned}$$

To ensure internal solutions that satisfy second order conditions, I assume $K_\theta(1) > \dfrac{v(\bar{\tau}-c)^2}{4(1-2v)^2}$, $K_{\theta\theta}(1) > \dfrac{2v^2(\bar{\tau}-c)^2}{(1-2v)^3}$, 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 a benchmark 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

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

$$\theta^{S} = K_{\theta}^{-1}\left(v\left(q_{i,B}^{S}\right)^{2}\right).$$

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 2A further describes firms' quality choices. Lemma 2 is useful for Corollary 2A.

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 2A describes the firms' internal and external quality choices.

Corollary 2A. 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.

Lemma 3 may provide insights in the recent merger of AOL and Time Warner. The FCC concluded that AOL's refusal to interoperate its Instant Messaging with its rivals' services implied market dominance. A refusal to interoperate is equivalent to choosing external quality equal to zero. However, AOL's Instant Messaging rivals also refuse to interoperate (Faulhaber, 2001), indicating that a choice of zero for external quality is a Nash equilibruim in this market. 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 operators and customers revealed that this may not have been the case. In some instances, the incumbent was subject to technical constraints that limited its ability to provide the interconnection capacity sought by the entrants. In other instances, customers generally did not understand network interconnection and believed that the entrants' service problem was caused by the entrants' 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' actions related to interconnection, the effect was to raise its rivals' quantity costs.

Corollary 3A further describes the firms' quantity choices and quality choices.

Corollary 3A. 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 3B. 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 output in market i is a strategic complement to the entrants' output 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's output in the first market affects its production in the second market more than does the smaller rival's output in the first market. Conversely, the larger firm's output in the first market affects the smaller firm's production in the second market more than does the smaller firm's own quantity 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 output has a greater feedback effect than does the smaller firm's production. 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 output in market *A*. This higher output 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* output. 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* output because of its lower market-*A* production. Just the opposite happens for the entrants. Assume that the incumbent unilaterally chooses a higher output in market *A*. In response, the entrants' lower their output in market *A*. Their lower quantity in market *A* lowers the internalized 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. 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. (2000) and raise questions about the US and EU regulators' restrictions on mergers. According to my analysis, a 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 in a simultaneous move game 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.