Broadband Internet: Open Access and Content Competition

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1 Introduction

The Internet is a collection of systems that are mostly open to one another in the sense that traffic flows freely from one system to another. For residential Internet users, the key systems are the telephone local access infrastructure and the Internet Service Provider (ISP). The telephone system is open to any ISP because it is a regulated common carrier. The ISPs are open to any web site, but this is a market outcome rather than a regulatory one. New "broadband" infrastructures, such as cable modems and fiber-optic networks, may not be common-carrier regulated and may not be open to all ISPs. "Open access" regulation has been proposed to force these new networks to be open to any ISP. At the same time, the openness of ISPs to web sites is also in question because America Online (AOL) and other large-scale, broadband-oriented ISPs are charging access fees to web sites.

In this paper, we model the effect of open access regulation on the number of networks that enter the market, the number of ISPs that enter the market, and the openness of those ISPs to content. The central tradeoff in the model concerns an ISP that sells subscriptions to consumers and also sells access and hosting to web sites. The ISP has an incentive to charge low prices to web sites in order to offer a large amount of content and attract subscribers. The ISP also has an incentive to charge high prices to web sites in order to limit the amount of competition between web sites and thus create rents which it can expropriate.[1]

The basic tradeoff of subscriber value versus web site profits exists for ISPs regardless of whether there is open access regulation or not. But we show that under open access regulation, an ISP's incentive to sign up an additional subscriber may be less than under vertical integration of the ISP with the network. Thus, it is possible that open access regulation tips the tradeoff more in the

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[1]This tradeoff, and hence the whole model, applies to other systems situations such as computer operating system providers who choose what software to support.

direction of web site profits and reduces the openness of ISPs. This means that open access does not necessarily improve consumer welfare.

1.1 Common Carriage and Regulated Monopoly Infrastructure

Ironically, the openness of current Internet access is firmly routed in traditional telephone regulation. Both the local and the long distance networks are common carriers — they must carry calls and data from all sources in a nondiscriminatory way. Common carriage has made it impossible for local telephone companies to monopolize Internet access because competitive ISPs are just a phone call away.

Equally important, all of this regulation applies to businesses and content providers. A firm can send Internet content to any consumer at nondiscriminatory prices. No firm could ally with a local telephone company to become, for example, the sole online music store accessible over the telephone lines. Both the technology and the regulation of the telephone network prohibit this. This nondiscriminatory principle is often referred to as "end-to-end."

The regulated telephone infrastructure has proved to be an excellent platform for the growth of the Internet economy. But the Internet's success has overwhelmed the infrastructure, as consumers demand higher speed, broadband access that allows them to view more video-intensive content. Broadband Internet requires new infrastructure. Initially broadband will reach households over upgraded cable television and telephone networks, but many firms are planning to build new networks using fiber-optic cable or wireless transmission.

Building broadband infrastructure raises questions about industry structure. The first is whether there can be multiple, competing infrastructures. Faulhaber and Hogendorn (2000) find that competition between multiple networks is likely to occur in most urban and suburban areas, provided that there are no regulatory barriers.

Another question is what will become of common carrier regulation and the competitive e-commerce environment it created. A current proposal is the regulatory intervention known as "open access," a weak cousin to common carriage that guarantees all Internet service providers nondiscriminatory access to the local network infrastructure. Some municipalities and current ISPs favor open access, but the Federal Communications Commission (FCC) has approached the policy very cautiously (FCC, 1999). Infrastructure owners, such as AT&T, are generally opposed to open access regulation.

In this paper we consider Internet competition with and without open access regulation. We introduce several innovations beyond the existing systems literature. We model multiple systems at different levels in the supply chain, including broadband access networks and service providers. We model the indirect network externality that results from content firms gaining access to the ISPs' subscribers. And we model free entry in all three of these sectors at the same time, which allows us to compare the extent of competition under different regulatory regimes. Although we couch the discussion in terms of Internet access, the analysis is relevant to open access debates in traditional telephone networks, computer operating systems, and other systems settings.

In the next section we discuss broadband Internet technology and the proposed open access regulation. In Section 3 we present a model of competition with "closed access," i.e. one service provider per network, and we extend the model to open access in Section 4. In Section 5 we compare the two regimes to each other and to the current Internet. We present extensions to the model and conclusions in section 6.

2 Regulation and Broadband Networks

2.1 The Broadband Internet Supply Chain

The broadband Internet industry is a supply chain, illustrated in Figure 1.[2] Since the Internet is a two-way network, the arrows in Figure 1 represent the dominant direction of information flows for most residential users. Internet users can also communicate with one another and host their own personal web pages, but even these activities are usually facilitated by upstream firms (see Coffman and Odlyzko (2000) for a differing view that two-way peer to peer communications are the most important Internet service).

The supply chain consists of three types of firms. *Content firms* sell their products and services over the network. The products are by no means limited to traditional media content. *Internet Service Providers* (ISPs) provide an intermediary function, allowing consumers to access content. *Networks* provide the physical infrastructure to transmit data to residential homes and small businesses.

2.1.1 Content Firms

Because the Internet is a general-purpose network, the meaning of "content" is much broader than in a traditional media context like cable television. While movies and TV-type programming are among the categories of broadband Internet content, the many retail sites on the Internet also provide content. Other popular Internet content includes real-estate listings, auctions, travel planning, and financial services.

Although Internet content is unlike traditional media, we discuss it in terms of the Steiner (1952) model of radio broadcasting. In that model, there are several types of programs (quiz shows, soap operas, etc.), and consumers are termed *satisfied* if they can listen to their most preferred program of each type. Within each type, there are classes: class A programs have popular performers and strong reputations, and class B programs are less popular. Whether classes are important on the Internet depends on whether class A content is scarce. If there are only a few class A content firms, then these firms will have bargaining

[2]The full supply chain has many more layers, or "platforms." Greenstein (1999) gives descriptions of these layers. Most of the layers are currently competitive markets, but Greenstein notes that continued competition is not assured.

power with respect to the ISPs that host them. If there are many class A content firms, then we simply redefine these popular firms as a different type.

Today's Internet is primarily a news and entertainment medium providing free, advertising-supported content. The Internet's role in conventional economic transactions is increasing, so we expect the share of advertising supported content to decline. For this reason and for simplicity, we do not discuss advertising here.

2.1.2 Service Providers

The next stage in the supply chain is the service provider. Currently, Internet Service Providers (ISPs) provide a simple, leased connection to the Internet backbone networks. When an ISP subscriber requests content from a particular web site, the ISP forwards that request to the Internet, and then forwards the content back to the subscriber. Since the ISP has no editing capability, it behaves like a common carrier, but this is a market outcome rather than a regulatory one.[3]

The traditional ISP model is likely to change (Greenstein 1999). There are two principal drivers of change in the service provider industry:

1. The popularity of America Online has shown that many consumers prefer an ISP which partially controls and categorizes content.

2. To provide broadband content at a high quality of service, more and more content is locally hosted. The ISP stores and processes content locally so that it can be reliably transmitted to subscribers' homes.

As a result of these changes, we expect a closer relationship to develop between content firms and ISPs. Most important, we expect that content firms will pay an access fee in order to be hosted on an ISP.

ISPs, however, are not the same as traditional media. In television, for example, networks choose a single program for every time slot. Spence and Owen (1977) show that networks are biased against offering programs with high costs or low price elasticities of demand. In contrast, ISPs are not constrained by time - they can offer every type of content simultaneously. In Steiner's terminology, an ISP has an incentive to host every possible type of content, because that brings each consumer closer to being satisfied all the time.

While ISPs would not exclude particular types of content, the question remains whether they would promote competition within a type. We focus on this question in the model below.

2.1.3 Networks

The physical link in the supply chain is the local access network, the connection between the ISP and the subscriber's home. Today, most Internet users access

[3] Many ISPs offer some filtering of content to prevent children from accessing adult sites or employees from accessing entertainment sites on the job. ISPs also provide de facto content discrimination by promoting certain web sites on the web browser start-up screen.

the Internet over the conventional telephone network, but broadband Internet will run over new types of access networks. There may be economies of scope if the service provider and network are integrated. The degree to which it is possible or desirable to have separate service providers and networks is a contentious issue. In this paper we assume there are no economies of scope. This assumption is designed to create a benchmark case in which vertical disintegration is not ruled out by technology.

2.2 The Open Access Debate

In 1998, AT&T purchased TCI, a major cable television company, and in 1999 it signed an agreement to purchase MediaOne, another cable company. It is upgrading these cable networks for two-way broadband communications. The upgrades will allow AT&T to offer broadband Internet, television, and telephone service over the same network. Most other cable television companies are making similar investments.

Unlike telephone, cable television is not a common carrier. Cable TV companies do face FCC and local requirements, but they are free to choose their programming and to negotiate with the producers of that programming. As a cable provider, AT&T expected to control the Internet content that would be transported over its upgraded cable television networks. In terms of the broadband supply chain, AT&T expected to be the exclusive ISP on its access network, and it contracted with Excite @Home, a company in which it has a significant stake, for this ISP role.

For AT&T to offer broadband Internet required approval of municipal cable regulatory boards, and the Portland, OR board objected to the lack of ISP choice. The board required AT&T to provide *open access* for any competitive ISPs. Several other local cable boards followed suit (FCC 1999). The case assumed a high profile. AT&T and its allies maintained that open access amounts to giving away their expensive infrastructure investment, while the cable boards and several ISPs argued from a common-carrier analogy. The arguments only concerned whether the network should offer open access to ISPs, not whether the ISP(s) should offer open access to content firms. Thus, the debate is not about true common carriage, but instead about a hybrid status somewhere between common carriage and proprietary networking.

The FCC has studied the arguments on both sides, and has concluded that open access is difficult to define and that its effects are difficult to predict (FCC 1999). Since many firms are planning to build competitive access infrastructure, the FCC has recommended against open access regulation for now. They have expressed concern that open access regulation may threaten facilities-based network competition.

2.3 Model Overview

In this paper, we study the open access debate using an economic model. The model provides a clear definition of one way open access regulation might operate, and studies the effects of such regulation. The model focuses on the amount of competition among content firms and among network infrastructure firms. In contrast, the current debate focuses on the ISP industry. The reason for the change in focus is that both content and network infrastructure are very innovative industries that have major effects on the overall economy. The ISP industry, on the other hand, is much more specialized, so its main economic significance is its indirect effects on content and infrastructure.

We now preview the model results:

1. In a model of closed access (one, and only one, vertically integrated ISP on each network), we show that the networks' access fees create a barrier to content entry. The access fees, in effect, allow the network to expropriate the oligopoly rents in the content industry. An increase in the free-entry number of networks lowers equilibrium access fees and increases content entry.

2. In a model of open access (every ISP available on every network), we show the stand-alone ISPs' access fees create a barrier to content entry, with results similar to closed access.

3. We compare the equilibrium outcomes of both models. The number of physical networks weakly decreases under open access. The number of ISPs and the amount of content available may increase or decrease under open access. We show how the comparison depends on the prospective industry structure of disintegrated ISPs.

3 A Model of Competition in Broadband Internet: Closed Access

We first model *closed access*. In this setting, each network offers one ISP, and we assume that the networks directly control their ISP. We refer to these integrated firms as *Networked Service Providers*, or NSPs.

3.1 The Game

There are M online households which value content and NSP services. Any number of NSPs may serve these households by building infrastructure.[4] A large number of content firms may buy access to one or more of the NSPs.

The firms compete in a four-stage game: (i) NSPs enter the market; (ii) NSPs choose access fees to charge to content firms; (iii) content firms enter the market by purchasing access to one or more NSPs; (iv) consumers subscribe to one NSP and purchase content. Consumers can only purchase content available on their chosen NSP.

[4]We assume that any network which entered would serve all of the households. Faulhaber and Hogendorn (2000) examine the decision of which households to serve.

3.1.1 Stage 1: NSPs Enter and Set Access Fees

In the first stage, firms decide whether to build a network and set up an integrated ISP. Let the number of NSPs that enter be K. There is a fixed cost of entry equal to F^{NSP}, which includes the capital cost of the network and the setup costs of the integrated ISP. We assume this cost is identical for each potential entrant.[5]

3.1.2 Stage 2: NSPs Set Access Fees

Each NSP sets an access fee for content firms. The access fee of network k, $k = 1 \dots K$, is a_k *per subscriber*. The assumption that the access fees are quoted per subscriber introduces a simplifying restriction: no content firm pays more to access a subscriber than it earns, on average, from selling to that subscriber.[6]

For each content firm that buys access, the NSP incurs a hosting cost per subscriber (total hosting costs rise in the number of subscribers because more users may simultaneously demand the same content).[7] Let the hosting cost be denoted h.

3.1.3 Stage 3: Content Firm Entry

In stage 3, content firms decide whether to enter, and if so which NSPs to buy access from. Each potential entrant offers the same type and class of content.[8]

We assume that there are no fixed costs of entry for content firms, other than the access fees. This assumption allows us to focus on the number of content firms without concern for the identity of each firm.[9]

Let the number of content firms that buy access to NSP k, $k = 1 \dots K$, be denoted n_k. The profile $\mathbf{n} = (n_1, \dots, n_K)$ describes the number of content firms available on every network. At the end of stage 2, this profile becomes common knowledge.

3.1.4 Stage 4: Consumers Subscribe to NSPs and Consume Content

In stage 4, each consumer purchases a subscription to one, and only one, NSP and consumes the content available on that NSP. The subscription choice depends on three factors: (i) the number of content firms available on an NSP

[5]Several different technologies are available for broadband networks, including cable modem, telephone digital subscriber line (DSL), and wireless. Each of these is likely to have a different fixed entry cost. Furthermore, incumbent cable television or telephone firms may have a lower entry cost.

[6]Without this restriction, there would be a continuum of equilibria in which one NSP charged a very large access fee while the others charged zero or even negative access fees.

[7]To maintain tractability, we do not consider economies of scale in hosting content. We conjecture that if they are not too strong, the model results still hold.

[8]Since NSPs have no incentive to exclude types, this assumption is equivalent to having many symmetric types, provided the cross-elasticities between types are low.

[9]Adding fixed costs is not a problem as long as there is enough producer surplus to cover them. The model takes the strong view that all bargaining power rests with the NSPs, which consequently expropriate all producer surplus.

(more is better), (ii) the consumer's idiosyncratic tastes for each NSP (based on marketing, network technology, the user interface, etc.), and (iii) the subscription fee. We model consumer choice using a multinomial logit demand.

The NSPs incur two costs for each subscriber. The traffic capacity cost, denoted t, is the constant marginal cost of maintaining network capacity and outside wiring for a household. The service cost, denoted s, is the constant marginal cost of account maintenance (e-mail, technical support, etc.) for a household.

Subscription fees are determined exogenously.[10] The subscription fee is denoted as a margin, m^{NSP}, plus the marginal cost of serving a household, i.e. it is equal to $m^{NSP} + t + s$. If the NSP were regulated, the regulator could set rates so that $m^{NSP} < 0$, redistributing rents to consumers.

Once consumers have subscribed to an NSP, they are restricted to buy content only from the content firms that are available on that NSP. Thus, content competition takes place separately on each NSP.

We do not model content competition explicitly. Instead, we make the form of competition as general as possible, specifying only the properties of the consumers' indirect utility functions and of the content producers' profit functions.

3.2 Equilibrium

We solve the game backwards to find a subgame perfect Nash equilibrium.

3.2.1 Stage 4: Consumers Subscribe to NSPs

Once consumers have subscribed to an NSP, they consume content. We assume that Spence (1976, pg. 410) is correct about industries with product differentiation:

> The entry of an additional product has several effects. It increases the surplus from the new product, but lowers the demand for existing products and causes them to contract output. In terms of the surplus, there are gains and losses. ...When the products are close substitutes and the cross elasticities are high, the extra surplus created by the entering product is lost through contractions of existing firms.

By stage 4, the number of content firms on each network, n_k, is fixed. Let the equilibrium content firm profit per consumer be $\pi(n_k)$ and let a typical consumer's indirect utility be $v(n_k)$. In keeping with Spence's assertion, the profits are decreasing in n_k while the indirect utility is increasing and concave in n_k. The total producer surplus (measured per subscriber) of all content firms on NSP k is $n_k\pi(n_k)$. The following assumption (an expansion of Spence's idea)

[10] This could be the result of regulation, as with cable television. It might also occur because the cross-elasticity with narrowband Internet is very high or because of pre-existing consumer expectations. We discuss relaxing this assumption in section 6.

characterize how content producer surplus varies with n_k:

Assumption Decreasing Surplus:

$$\frac{d^2}{dn_k^2} n_k \pi(n_k) \leq 0 \text{ and } \exists \hat{n} \geq 1 \text{ s.t. } \frac{d}{dn_k} n_k \pi(n_k) < 0 \ , \ \forall n_k > \hat{n}$$

For large enough n_k, we assume competition reduces total content producer surplus. *Decreasing Surplus* may hold because more content firms on a given NSP result in lower content prices on that NSP.[11] Other competitive factors, including limited economies of scale, advertising and brand awareness, and customer communities (chat rooms, message boards, etc.) could also lower profits as the number of content firms increases on a given NSP.[12]

Consumers choose NSPs according to the multinomial logit model. Each consumer receives two types of utility: (i) the *content-based utility*, equal to $v(n_k) - (m_{NSP} + t + s)$, is the utility from content consumption minus the subscription fee; (ii) the *NSP-specific utility* is a random variable representing the idiosyncratic preferences of each consumer for each NSP. In the multinomial logit model, the random variable takes the type 1 extreme value distribution.[13]

The strength of the NSP-specific utility is parameterized by σ^{NSP}, which is proportionate to the variance of the random variable. The larger is σ^{NSP}, the stronger are the tastes of each consumer for his or her preferred NSP, regardless of the content-based utility available on other NSPs.

The outcome of the stage 4 subscription decision is a consumer choice function, $\Phi_k(\mathbf{n})$, which gives the probability that a consumer chooses NSP k given the profile of content firms available on all the NSPs. The form of this function is:

$$\Phi_k(\mathbf{n}) = \frac{\exp\left(\dfrac{v(n_k) - (m^{NSP} + t + s)}{\sigma^{NSP}}\right)}{\displaystyle\sum_{j=1}^{K} \exp\left(\dfrac{v(n_j) - (m^{NSP} + t + s)}{\sigma^{NSP}}\right)} \tag{1}$$

The market share Φ_k increases in the number of content firms on NSP k and decreases in the number of content firms on NSPs other than k. Since the total number of consumers is M, the number of subscribers to NSP k is $\Phi_k(\mathbf{n})M$.

[11] Prices fall in n_k only if content firms can charge different prices on different NSPs. For example, suppose one NSP hosted four movie rental firms, and another hosted eight. A movie rental firm that was hosted by both NSPs would want to charge a higher price on the NSP where it had fewer competitors. (Actually, this only occurs out of equilibrium in the symmetric case we study below.)

[12] *Decreasing Surplus* is closely related to the assumption that all content is of the same type. For example, *Decreasing Surplus* is likely to hold for the n^{th} online music store but not likely to hold if there are $n - 1$ music stores and the n^{th} content firm is a travel service.

[13] In the literature on multinomial logit models, the content-based utility is often referred to as the "observed" or "systematic" utility because it varies with parameters that are under the control of the firms. The NSP-specific utility is referred to as "unobserved" or "unsystematic" because it is based on consumer tastes that are beyond the control of the firms.

3.2.2 Stage 3: Entry of Content Firms

The operating profit of one of the n_k content firms on NSP k is $\pi(n_k)\Phi_k(\mathbf{n})M$. The total access fee on NSP k is $a_k\Phi_k(\mathbf{n})M$. Content firms buy slots until profits go to zero (free entry), so the number of content firms on NSP k solves

$$(\pi(n_k) - a_k)\Phi_k(\mathbf{n})M = 0 \tag{2}$$

The number of content firms on each NSP is obtained by simultaneously solving (2) for $k = 1 \ldots K$.[14] Because $\Phi_k(\mathbf{n})$ is always positive, the free entry condition (2) holds only for some number of content firms $n(a_k)$ that solves

$$\pi(n(a_k)) - a_k = 0 \tag{3}$$

The function $n(a_k)$ characterizes the equilibrium outcome of stage 3. Equation (3) has two important implications:

1. Because π is monotonic decreasing, there a one-to-one mapping of a_k to n_k; thus, an NSP directly chooses its number of content firms by setting its access fee.

2. The assumption of free entry of identical content firms means that all bargaining power rests with the NSP. All profits earned by the content firms are expropriated through the access fee.

3.2.3 Stage 2: Oligopolistic Competition Between NSPs

In stage 2, the NSPs noncooperatively choose access fees. We saw from equation (3) that we can equivalently treat this as a choice of the number of content firms, and it is simpler to do so. For any n_k, the NSP receives a per-subscriber access fee $\pi(n_k)$ from each of the n_k content firms. The total profit of NSP k, from both access and subscription fees, is

$$(n_k(\pi(n_k) - h) + m^{NSP})\Phi_k(\mathbf{n})M \tag{4}$$

In equilibrium, all NSPs simultaneously maximize (4). In its essence, this is a vertical differentiation problem, and Shaked and Sutton (1982) showed that such problems often have asymmetric solutions. This is not necessarily the case for multinomial logit demand. The appendix, which draws on (Anderson, de Palma and Thisse 1992), shows that under fairly general conditions there is a symmetric equilibrium in which each NSP hosts n^* content firms.[15] From here on, we assume the symmetric equilibrium exists and discuss its properties

[14] This problem is similar to the one studied by Church and Gandal (1992). In their model, it is possible, due to coordination failures, for zero content firms to locate on one of the NSPs. Here we expect this does not happen because the networks also offer telephone and cable television, which guarantees some demand even when $n_k = 0$. The logit model incorporates this intuition.

[15] There may also be an asymmetric equilibrium for low σ^{NSP}, but this can only be found numerically.

exclusively.[16] For a given number of NSPs, K, the first order condition at this equilibrium is

$$\frac{d}{dn_k}n^*\pi(n^*)\frac{M}{K} + (n^*(\pi(n^*) - h) + m^{NSP})\frac{d}{dn_k}\Phi_k(\mathbf{n})M = 0 \tag{5}$$

The first term in (5) represents the *profit effect*: increasing the number of content firms reduces content producer surplus. Since the content producer surplus is expropriated by the NSP via the access fee, the profit effect influences the NSP to reduce the number of content firms.

The second term in (5) is the *demand effect*: increasing the number of content firms increases the market share of the NSP. The demand effect influences the NSP to expand the number of content firms.

The existence of a symmetric equilibrium depends on demand. An s-curve demand function (logit, probit, etc.) will produce a symmetric equilibrium (under the proper conditions) because there are diminishing returns to adding content. Demand systems that are linear or quadratic in content-based utility (such as conventional differentiated Bertrand demand) do not have this property. In these demand systems, one NSP could add content until demand for its competitors went to zero. Let $n^{CA}(K)$ be the number of content firms given implicitly by (5), with the superscript CA denoting "closed access." This is the equilibrium outcome of stage 2. We note an important property of this equilibrium:

Property 1 $\frac{dn^{CA}(K)}{dK} > 0.$

An exogenous increase in the number of NSPs makes the industry more competitive. The NSPs compete harder to attract consumers by increasing content.

3.2.4 Stage 1: Entry of NSPs

Assuming that the NSPs are sufficiently differentiated to achieve a symmetric equilibrium, they enter the market until

$$(n^{CA}(K)(\pi(n^{CA}(K)) - h) + m^{NSP})\frac{M}{K} = F^{NSP} \tag{6}$$

We denote the solution to (6) by K^{CA}. The amount of content available on each NSP in free entry equilibrium is $n^{CA}(K^{CA})$.

We now recap the equilibrium outcome of the closed access game. In stage 4, there is a consumer indirect utility function $v(n_k)$, a content firm profit function per consumer, $\pi(n_k)$, and a consumer subscription choice function $\Phi_k(\mathbf{n})$. In stage 3, the equilibrium number of content firms on each network, given the

[16] It is possible that an asymmetric equilibrium exists as well as the symmetric one. Based on the reasoning in Rhee (1996), we believe that as σ^{NSP} increases, the asymmetric equilibrium converges to the symmetric one.

network's access fee, is $n(a_k)$. In stage 2, there is a symmetric equilibrium in which each network sets its access fee so that it hosts $n^{CA}(K)$ content firms. In stage 1, the free entry equilibrium number of NSPs is K^{CA} and the amount of content available on each network is $n^{CA}(K^{CA})$.

3.3 Discussion

In this section we discuss the comparative statics of the equilibrium amount of content, $n^{CA}(K^{CA})$. (The mathematical details are in the appendix.) The variance parameter σ^{NSP} determines how strongly consumers respond to changes in the number of content firms. Its effect on equilibrium content is

$$\frac{dn^{CA}(K^{CA})}{d\sigma^{NSP}} = \frac{dn^{CA}(K^{CA})}{d\sigma^{NSP}} + \frac{dn^{CA}}{dK}\frac{dK^{CA}}{d\sigma^{NSP}}$$

There is both a direct effect and an indirect effect. The direct effect occurs because the amount of differentiation determines how hard NSPs compete for customers. The indirect effect occurs because a change in differentiation could affect profits enough to change the free-entry equilibrium number of NSPs. The direct effect of a change in σ^{NSP} is:

Property 2 $\frac{dn^{CA}(K)}{d\sigma^{NSP}} < 0.$

The parameter σ^{NSP} provides an index of how competitive the NSP industry is. As σ^{NSP} increases, the NSPs become more differentiated from one another, and compete less strenuously for market share.[17]

The subscription fee profit margin, m^{NSP}, determines how much incentive NSPs have to attract additional customers. Its effect on equilibrium content is

$$\frac{dn^{CA}(K^{CA})}{dm^{NSP}} = \frac{dn^{CA}(K^{CA})}{dm^{NSP}} + \frac{dn^{CA}}{dK}\frac{dK^{CA}}{dm^{NSP}}$$

Changes in m^{NSP} also have a direct effect and an indirect effect operating through the free-entry number of NSPs. The direct effect of a change in m^{NSP}, is:

Property 3 $\frac{dn^{CA}(K)}{dm^{NSP}} > 0.$

As the subscription fee profit margin rises, there is more incentive to attract additional consumers. The way to attract these consumers is by hosting more content firms. If the subscription fee were regulated (as cable television subscription fees are), then Property 3 implies that a seemingly pro-consumer reduction in the subscription fee also reduces the amount of content available. The effect on consumer surplus is ambiguous, not definitely positive as the regulator might initially suppose.[18]

[17] If σ^{NSP} increased enough to raise the free-entry number of NSPs, then the amount of content hosted could rise instead of fall.

[18] If m^{NSP} increased enough to raise the free-entry number of network/SPs, then the amount of content could rise even more.

4 Open Access: Many ISPs on Each Network

Under open access, the network and ISP are not integrated within the same company. Consumers choose a network (if there is more than one physical network to choose from) and also choose an ISP. We assume these choices are made in "mix-and-match" fashion - any ISP can be used along with any network.

It is crucial to the model outcomes that the networks maintain a customer relationship. This allows them to differentiate their product and engage in conventional oligopolistic competition. In an alternative setting, only the ISP would maintain a customer relationship, with the networks acting as upstream suppliers. In that setting, there would be a bargaining relationship between the ISPs and the networks.

We now alter the model of section 3 to accommodate stand-alone ISPs. The main difference is that content firms pay access fees only to the ISPs; otherwise most of the results developed above carry over.

4.1 The Game

Networks, ISPs, content firms, and consumers play a five-stage game: (i) networks enter the market; (ii) ISPs enter the market; (iii) ISPs choose access fees for content firms; (iv) content firms enter and purchase access on one or more ISPs; (v) consumers subscribe to one network and one ISP in mix-and-match fashion, and they purchase content available on their chosen ISP.

4.1.1 Stage 1: Networks Enter

In the first stage, firms decide whether to build a network. Let the number of networks that enter be J. There is a fixed cost of entry equal to F^N, which includes the capital cost of the network. This cost is identical for each potential entrant.

The networks may charge an *infrastructure fee* to each ISP. However, a it seems natural to assume that a component of open access regulation would be explicit or implicit limits on such fees, so we ignore them.

4.1.2 Stage 2: ISPs Enter

In the second stage, ISPs enter. Let the number of ISPs that enter be L. There is a fixed cost of entry equal to F^{ISP}. This cost is identical for each potential entrant.

4.1.3 Stage 3: ISPs Set Access Fees

The access fee of ISP l, $l = 1 \ldots L$, is a_l per subscriber. For each content firms that buys access, the ISP incurs a hosting cost per subscriber, denoted (as before) h. At the end of stage 3, the ISP access fees become known to all.

4.1.4 Stage 4: Content Firm Entry

In the third stage, content firms decide whether to enter the market, and if so which ISPs to buy access from. In other respects, content firms are the same as under closed access. The number of content firms that buy access to ISP l, $l = 1 \ldots L$, is n_l. The profile $\mathbf{n} = (n_1, \ldots, n_L)$ describes the number of content firms available on every ISP. At the end of stage 4, this profile becomes common knowledge.

4.1.5 Stage 5: Consumers Subscribe to Networks and ISPs and Purchase Content

Consumers make two independent decisions: which network to subscribe to and which ISP to subscribe to. For both decisions, we represent demand by the multinomial logit. The networks incur the traffic capacity cost, t, for each subscriber. The ISPs incur the service cost, s, for each subscriber. Subscription fees for both networks and ISPs are determined exogenously. We denote the network subscription by a margin, m^N, plus the marginal cost of serving a household, i.e. it is equal to $m^N + t$. Similarly, we denote the ISP subscription by $m^{ISP} + s$.

Consumers buy content from the content firms, but they are limited to those content firms that are available on the ISP they have subscribed to. Thus, content competition takes place separately on each ISP. As in the closed access model, we make the form of content competition as general as possible.

4.2 Equilibrium

We solve backwards to find a subgame perfect Nash equilibrium.

4.2.1 Stage 5: Consumers Subscribe to Networks and ISPs and Purchase Content

Once consumers have subscribed to a network and an ISP, content competition takes places as in the closed access model. There is an increasing, concave indirect utility function $v(n_l)$ and a content firm profit function $\pi(n_l)$. The assumption *Decreasing Surplus* continues to apply.

Consumers choose networks and ISPs according to two, independent multinomial logit models. The choice of ISPs is determined by two types of utility: (i) the *content-based utility*, equal to $v(n_l) - (m^{ISP} + s)$, is the utility from content consumption minus the subscription fee; (ii) the ISP-specific utility is a random variable representing a consumer's idiosyncratic preferences for an ISP. The strength of the ISP-specific utility is parameterized by σ^{ISP}, which is proportionate to the random variable's variance.

One outcome of stage 5 is a consumer ISP choice function, $\Phi_l(\mathbf{n})$, which gives the probability that a consumer chooses SP l given the profile of content firms available on all the SPs. The form of this function is:

$$\Phi_l(\mathbf{n}) = \frac{\exp\left(\dfrac{v(n_l) - (m^{ISP} + s)}{\sigma^{ISP}}\right)}{\displaystyle\sum_{j=1}^{L} \exp\left(\dfrac{v(n_j) - (m^{ISP} + s)}{\sigma^{ISP}}\right)}$$

Since the total number of consumers is M, the number of subscribers to ISP l is given by $\Phi_l(\mathbf{n})M$.

Consumers also make a completely separate decision about which network to subscribe to. Because the consumers can choose any ISP over any network, the choice of network is not affected by the number of content firms available on the ISPs. There are, as before, two types of utility. The "content"-based utility is just the negative of the subscription fee, $-(m^N + t)$, because there is no content directly tied to the network. The network-specific utility is a type 1 extreme value random variable with variance proportionate to σ^N. The probability that a consumer chooses network k is

$$\frac{\exp\left(\dfrac{-(m^N + t)}{\sigma^N}\right)}{\displaystyle\sum_{j=1}^{J} \exp\left(\dfrac{-(m^N + t)}{\sigma^N}\right)} = \frac{1}{J}$$

Note that a principle effect of open access is to remove the quality differences between networks, and therefore demand for them will always be symmetric.[19]

4.2.2 Stage 4: Entry of Content Firms

In the fourth stage, content firms pay a_l to be hosted on ISP l. Content firms buy access to each ISP until profits go to zero (free entry), so the number of firms that enter on any given ISP is the solution to

$$(\pi(n_l) - a_l)\Phi_l(n)M = 0 \tag{7}$$

The outcome of this stage is a function $n(a_l)$ that solves (7).

4.2.3 Stage 3: ISPs Set Access Fees

The competition between ISPs is similar to that between integrated networks under closed access. Again there is a one-to-one mapping of access fees to the number of content firms, so the ISP's choice is recast as a choice of n_l.

The total profit of ISP l is

$$(n_l(\pi(n_l) - h) + m^{ISP})\Phi_l(\mathbf{n})M \tag{8}$$

[19] Networks do differ in service quality, uptime, tech support, etc., but strategic choice of these variables is beyond the scope of this model.

The proof that a symmetric equilibrium exists (for sufficiently high σ^{ISP}) is the same as under closed access. At the symmetric solution, each ISP's market share is $1/L$, and the condition for the equilibrium number of content firms is

$$\frac{d}{dn} n^* \pi(n^*) \frac{M}{L} + (n^*(\pi(n^*) - h) + m^{ISP}) \frac{d}{dn} \Phi_l(\mathbf{n}) M = 0 \tag{9}$$

The outcome of stage 3 is a function $n^{OA}(L)$ given implicitly by (9), where the superscript OA refers to "open access."

4.2.4 Stage 2: ISPs Enter the Market

ISPs enter the market until

$$(n^{OA}(L)(\pi(n^{OA}(L)) - h) + m^{ISP}) \frac{M}{L} = F^{ISP} \tag{10}$$

The equilibrium of stage 2 is the solution to (10), denoted L^{OA}. Note that L^{OA} is independent of the number of networks. While this may seem counter-intuitive, it is the direct effect of open access regulation as it has been defined above.[20]

4.2.5 Stage 1: Networks Enter the Market

Since the network subscription fee is exogenous, the networks have no further choice variables — network competition is deterministic. The total profit of network k is $(m^N/K)M$, and we can write the free entry number of networks in closed form:

$$J^{OA} = \frac{m^N M}{F^N} \tag{11}$$

We now recap the equilibrium outcome of the open access game. In stage 5, there is a consumer indirect utility function $v(n_l)$, a content firm profit function per consumer, $p(n_l)$, a consumer ISP subscription choice function $\Phi_l(\mathbf{n})$, and a consumer network subscription choice which is symmetric in this model. In stage 4, the equilibrium number of content firms on each ISP, given the ISP's access fee, is $n(a_l)$. In stage 3, there is a symmetric equilibrium in which each ISP sets its access fee so that it hosts $n^{OA}(L)$ content firms. In stage 2, the free entry equilibrium number of ISPs is L^{OA} and the amount of content available on each ISP is $n^{OA}(L^{OA})$. In stage 1, the free entry equilibrium number of networks is J^{OA}.

4.3 Discussion

Because the open access model is similar to closed access, the comparative statics results carry over directly. An interesting additional result is that under open access, the network subscription fee has no effect on content:

[20] This conclusion is very sensitive to the assumption that networks do not charge infrastructure fees.

Property 4 $\dfrac{dn^{OA}(L)}{dm^{N}} = 0.$[21]

Property 4 may have policy implications. In the past regulation has applied only to the infrastructure itself, not to firms that use infrastructure.[22] While cable television and telephone rate regulation are already in place, it appears politically very unlikely that a burgeoning Internet industry like ISPs would come under rate regulation.Therefore, rate regulation appears much more likely for integrated NSPs or stand-alone networks than it does for stand-alone ISPs.

With this disjunction between network and ISP rate regulation in mind, consider the role of regulation in the current open access battle. Suppose that the subscription fee of the network were regulated. Under open access, the regulator has a fairly strong incentive to reduce network subscription fees, although this does reduce network entry. Under closed access, there is an additional effect of rate regulation: it reduces the amount of content available. Thus, the regulator is more likely to lower subscription fees under open access than under closed access.

In the United States, the FCC controls cable rates, while municipal regulators are asserting their right to impose an open access requirement. Perhaps the goal of municipalities is lower subscription fees for their constituents, without regard for the effect on the overall content industry. If so, then mandating open access is a good way to increase the pressure on the FCC to lower rates.

5 The Current and Future Internet

In this section we compare open to closed access, emphasizing the number of content firms available under each regime. We apply the model to the current Internet and discuss the changes that are occurring in the parameters.

5.1 A Comparison of Open and Closed Access

The market structure of stand-alone ISPs and stand-alone networks would probably differ from that of integrated NSPs, and these differences are the key to comparing open to closed access. We make five assumptions that reflect the likely differences in the parameters and informally discuss their effects on equilibrium outcomes.

Assumption: Stand-alone ISPs are less differentiated ($\sigma^{ISP} < \sigma^{NSP}$). This leads to a strength and a weakness of open access. Stand-alone ISPs are more competitive with one another than integrated NSPs, which means they will tend to host more content. On the other hand, we have seen that hosting more content is equivalent to lower access fee profits, and lower profits tend to inhibit entry of stand-alone ISPs.

[21] This property depends on there being no infrastructure fees paid by ISPs to networks. If there were, there would be indirect effects of network subscription fees on content, which would operate through the infrastructure fee.

[22] Trucking is an exception.

Assumption: Stand-alone ISPs have lower subscription fee margins ($m^{ISP} < m^{NSP}$). Stand-alone ISPs sell just one service to consumers, while NSPs sell broadband hookups, telephone, cable television, and perhaps other services in addition to ISP services. For this reason, stand-alone ISPs have less to gain by signing up an additional customer, and will therefore have less incentive to host content.

Assumption: Stand-alone ISPs have lower fixed costs ($F^{ISP} < F^{NSP}$). This seems to be the main argument behind open access. Many industry observers think that the bulk of NSP fixed costs are the network infrastructure, and that therefore the fixed costs of a stand-alone ISP are much lower. Low fixed costs would produce much more entry of stand-alone ISP firms.

Assumption: Stand-alone networks have lower fixed costs ($F^N < F^{NSP}$). Under open access, networks would not provide ISP services, so their fixed costs would also be reduced. However, if the network infrastructure is the major fixed cost, this effect would be small and would be unlikely to increase network entry.

Assumption: Stand-alone networks have lower profits per consumer. This happens for two reasons. First, since stand-alone networks do not sell ISP services, we expect their subscription fee profits are lower ($m^N < m^{NSP}$). Second, and more important, stand-alone networks do not sell access to content firms, so they miss out on that side of the market. The lower profits would tend to discourage network entry; this is the main reason why opponents of open access say that it would inhibit facilities-based competition.

We would like to combine these five differences in order to determine the conditions under which open access would (i) lead to many stand-alone ISPs entering the market, (ii) lead to a great deal of content being hosted, and (iii) not reduce the number of networks. These conditions are criteria for the success of open access policy.

We first discuss the number of networks. The free entry number of open access networks, J^{OA}, is given by (11). Using (11), it is easy to show that $J^{OA} < K^{CA}$ if

$$m^N < \frac{K^{CA} F^N}{M}$$

To interpret this inequality, suppose $K^{CA} > 2$, indicating two or more NSPs under closed access. Then under open access, there are weakly fewer networks as long as the network subscription profit margin is less than twice the infrastructure cost per subscriber. Such a high profit margin is unrealistic, so we conclude that this model predicts that open access would weakly reduce the number of networks.[23]

Comparisons of the number of ISPs and the amount of content are more ambiguous. In the appendix, we show that it may require more stand-alone ISPs than integrated NSPs just to provide the same amount of content (if m^{ISP} is much lower than m^{NSP}). We also show that it is possible that fewer stand-

[23]In the case of $K^{CA} = 1$, the inequality probably does not hold. However, entry of an additional network would require the subscription fee to exceed $K^{CA} + 1 = 2$ times the fixed cost per subscriber. Again, we state that this is unlikely.

alone ISPs will enter under open access than would NSPs under closed access (if $F^{NSP} - F^{ISP}$ is not very large and σ^{ISP} is much less than σ^{NSP}).

Given this ambiguity, we would like to derive relationships between the parameters that illustrate the tradeoffs. This is not possible for the very general form of content competition in which we assumed only a concave indirect utility $v(n_k)$ and a producer surplus $n_k\pi(n_k)$ that conforms to *Decreasing Surplus*. Therefore, we now assume that the relative changes in these functions are constant over the relevant interval of n. Formally, the assumption is:

Assumption Surplus Division: $\dfrac{v'(n)}{-\left(\frac{d}{dn}n\pi(n) - h\right)}$

The interpretation of *Surplus Division* is that by giving up \$1 in access fee profits (by letting in additional content firms), the NSP or ISP can give consumers R dollars of consumer surplus.[24]

Applying *Surplus Division*, we can rearrange and simplify the first order conditions for the number of content firms, (5) and (9), and then substitute them into the free entry conditions for K^{CA} and L^{OA} to obtain

$$K^{CA} = 1 + \left(\frac{F^{NSP}}{M}\right)^{-1}\frac{\sigma^{NSP}}{R} \qquad L^{OA} = 1 + \left(\frac{F^{ISP}}{M}\right)^{-1}\frac{\sigma^{ISP}}{R} \tag{12}$$

Equation (12) indicates that the free entry number of firms decreases in the fixed cost per household and increases as the firms become more differentiated from one another (higher σ).[25] We can see why entry falls in R by reversing our discussion of *Surplus Division*: if R is high, a reduction in n reduces consumer surplus, but does little to increase profits. Thus a high R is consistent with less opportunity to make profits from access fees.

An interesting feature of (12) is that the subscription fee profit margins do not appear. This is because NSPs and ISPs compensate for changes in their subscription profit margins by changing their access fees.

The comparison K^{CA} and L^{OA} is now straightforward: there are more ISPs under open access than NSPs under closed access if $\frac{\sigma^{ISP}}{\sigma^{NSP}} > \frac{F^{ISP}}{F^{NSP}}$. We discuss whether this inequality is likely to hold in the next section.

To compare equilibrium content under the two regimes, we use (12) to find and compare $n^{CA}(K^{CA})$ and $n^{OA}(L^{OA})$. At the free entry equilibria, open access results in more content if

$$\frac{\sigma^{NSP} - \sigma^{ISP}}{R} + \frac{F^{NSP} - F^{ISP}}{M} > m^{NSP} - m^{ISP} \tag{13}$$

[24] Since v is increasing concave and $n\pi(n)$ is decreasing concave, *Surplus Division* is a linear approximation to a value which actually decreases in n. We conjecture that it produces approximately correct results for n in a limited interval and v and $n\pi(n)$ not too concave. The concavity of v and $n\pi(n)$ depends on how broadly we define a "type" of content. The more broadly types are defined, the more differentiated an additional content firm will be. A more differentiated firm adds more to consumer utility and reduces industry profits less. Thus, more broadly defined types correspond more closely to *Surplus Division.*

[25] The algebra used to derive these equations is not valid when K^{CA} or L^{OA} equals 1. Thus, if the equations indicate a monopoly outcome, we must check separately to be sure that even a monopoly is profitable enough to enter.

The first term in (13) shows that stand-alone ISPs are less differentiated than NSPs. This means that open-access ISPs would compete more vigorously and host more content even if the number of ISPs were no greater than the number of NSPs.

The second term in (13) shows that the fixed costs per subscriber are lower in the open-access ISP industry than in the closed-access NSP industry. This means that there will be more entry of stand-alone ISPs than NSPs. The larger number of firms will compete harder to attract customers by hosting content.

The term on the right hand side of (13) shows that stand-alone ISPs have less to sell their customers and therefore have lower profits margins per subscriber. This gives them less of an incentive to attract additional subscribers by adding content.

We expect stand-alone ISPs would be less differentiated, have lower fixed costs, and have lower subscription profits than integrated NSPs. Based on equation (13), the effect of open access on content would depend on the relative strength of these effects. That, in turn, depends on the future evolution of the ISP industry.

5.2 Internet Evolution Under Closed and Open Access

Today the Internet is similar to the open access model because many ISPs are available over the telephone network. Given the small scale of many ISPs, it appears that the fixed costs are very low. The intense price competition between ISPs suggests that they are not very differentiated from one another, so σ^{ISP} also seems to be low. Currently the low fixed costs outweigh the lack of product differentiation, so there are large numbers of ISPs in the market.

The current trend in the ISP industry is to introduce advanced technologies and services that create higher fixed costs and more product differentiation (Greenstein, 1999). The trend toward product differentiation is illustrated by the increased dominance of America Online, a company that was initially expected to lose market share relative to smaller, lower-priced rivals. The merger of MindSpring and EarthLink also signals a change of ISP market structure. The advent of broadband local access will bring more changes as ISPs adapt to increasingly demanding content.

It is too early to know where this evolution of the ISP industry will lead. But all indications are that there will be fewer, more differentiated ISPs. In the model, we showed that an increase in ISP horizontal differentiation reduces the number of content firms. This leads to an important conclusion: even if consumers continued to access the Internet using the telephone, there would likely be changes in Internet market structure. If the ISP industry continues to consolidate and become more differentiated, then the model predicts that advanced forms of content will be available from fewer firms than the current cornucopia on the web.

5.3 Scenarios for Internet Evolution

This section presents four scenarios for the future of the ISP industry. It assumes that under closed access, there would be a relatively concentrated and uncompetitive group of NSPs (σ^{NSP} and F^{NSP} high), and compares a hypothetical open-access ISP industry to that benchmark.

5.3.1 Scenario 1: The Current Internet Industry

The current Internet industry is characterized by very low fixed costs and near-perfect competition between ISPs (ignoring AOL), as opposed to much higher costs and probably more product differentiation between networks. If these conditions did not change with the advent of broadband networks, open access would produce many, very competitive ISPs. Equation (13) predicts intense content competition in this setting. The drawback that there would be fewer networks under open access.

5.3.2 Scenario 2: Main Street

Suppose that ISP competition is becoming less intense (as suggested by AOL's continued high market share) but that it remains inexpensive to set up an ISP. Under open access, the model predicts a lot of ISP entry, but the ISPs can charge high access fees and therefore content competition is muted. In a sense, open access creates a Main Street store atmosphere among ISPs: there are many firms, but the goods sold by them (the content) have high prices and limited selection. Again open access results in fewer networks, and now the tradeoff seems less good. Open access provides just a little more content competition, in exchange for fewer networks.

5.3.3 Scenario 3: The Airlines

If scale and technology are the major drivers of change in the ISP industry, then ISPs will become larger. If they also compete vigorously relative to NSPs, then there will not be many more open access ISPs than closed access NSPs; indeed there may well be fewer. The amount of content could increase or decrease, depending on how much more competitive the stand-alone ISPs are, but there would clearly not be as much content as in Scenario 1. As always, the model predicts a smaller number of networks under open access.

This tradeoff has some similarities to airline deregulation. Under regulation, airlines were tied to certain airports and/or certain routes, with the resulting profits supporting a large number of airlines. Deregulation led to falling profit margins and fewer, larger-scale airlines. In some ways "content" variety fell, since the number of cities with jet service and the number of city-pairs with non-stop service fell.

Another lesson from the airlines is that firms will try to find unforeseen ways to control infrastructure. Since deregulation, the primary airline competitive strategy has been avoiding "open access" to airports by creating hub-and-spoke networks.

5.3.4 Scenario 4: IBM and Microsoft

The worst case scenario for open access is that the ISP industry is becoming expensive to enter and uncompetitive, just as the network industry is thought to be. Indeed, it seems possible, given the size of AOL and the threat it poses even to AT&T, that the ISP industry is actually more expensive to enter and less competitive than the stand-alone network industry. Under open access in this scenario, the model predicts a small number of ISPs, each hosting limited content. Thus, open access is not really the main issue for competition policy in this scenario; the main issue is the intrinsic uncompetitveness of the ISP industry.

This scenario has some similarities to the rise of Microsoft. For years antitrust policy focused on IBM's supposed control of computer infrastructure, and no one expected that the real market power lay in the operating system.

5.3.5 Discussion

Currently the Internet is in scenario 1, and in that scenario open access is very positive for content competition. Decision-makers in the open access debate should be mindful that the ISP industry may be moving away from scenario 1. In general, the direction of movement seems to be toward scenarios 3 or 4, since scale is increasing and competitive intensity may or may not be diminishing. In both scenarios 3 and 4, the effects of open access are not obviously beneficial: they produce less network competition in exchange for ambiguous effects on content competition.

It is also worth noting that the level of ISP industry support for open access regulation is probably correlated with the prospective market structure under open access. The leading firms in the ISP industry have much to gain from open access if the industry is moving toward scenario 3 or especially 4. This should introduce a note of skepticism into the thinking of policy-makers.

6 Conclusion

6.1 Extensions and Suggestions for Future Research

6.1.1 The Online Population

Throughout the model, the number of consumers, M, is assumed constant. Once demand for broadband has reached a saturation level, this assumption will be justified. During the industry's growth phase, the number of online consumers is growing as the value of buying broadband access increases. The effect on content of introducing an endogenous M would be to strengthen the demand effect: more content would bring more people online. The probable result would be greater content competition in equilibrium (under either closed or open access).

6.1.2 Endogenous Subscription Prices

If subscription prices were determined endogenously, the game becomes more complicated and requires numerical methods to find an exact solution. Rhee (1996) shows that a symmetric equilibrium still exists for sufficiently large σ. Using Rhee's methods, the subscription prices approach a limit of $\frac{K}{K-1}\sigma^{NSP} + t + s$ under closed access and $\frac{J}{J-1}\sigma^{N} + t$ and $\frac{L}{L-1}\sigma^{ISP} + s$ for the networks and ISPs respectively under open access. If we apply this limiting case along with *Surplus Division*, we can show that open access provides more content if $R < 1$ and less content if $R > 1$.[26]

6.1.3 Geographical Footprints

In this model, the networks and ISPs are assumed to cover the same geographic area, so that both types of firms compete for the same number of households, M. In the current race to upgrade cable networks for two-way broadband capability, many of the cable systems remain confined to a small geographical area. These cable systems then contract with a single ISP (for the time being, closed access is the rule). Currently, the broadband ISPs are dominated by two firms, Excite@Home and RoadRunner.

If this pattern continues, the ISPs may have a larger geographic footprint than the networks. This suggests that the ISPs would be very large scale, creating an even more decisive movement to scenarios 3 or 4 in Table 1. A full analysis would include a bargaining decision as independent networks formed alliances with national ISPs.

6.1.4 Partial Vertical Integration: Networks Own One ISP

The Portland, OR open access proposal and its imitators do not include full "unbundling," in which the networks would be prevented from owning their own ISPs. Therefore, it is likely that one of the ISPs on each open access network would actually be owned by the network. This has two implications for the model:

1. Assuming these network-owned ISPs continued to be proprietary, the mix-and-match assumption would be partially violated. It would not be possible to access, for example, AT&T's ISP over Bell Atlantic's broadband network. If each of the network's proprietary ISPs were equally "good," this would cause no change in the model. But if one network had an especially attractive ISP, it would skew consumers' choices of which network to subscribe to.

[26] Note this assumes away any additional profit margin the network could earn from selling non-Internet-related services like telephone and television.

2. Because the network would have some stake in the ISP industry (and, through access fees, in the content industry), its behavior would be changed. The network-owned ISP would have a greater incentive to provide content than the non-network owned ISPs, because more content would bring in more subscribers to the network as well as the ISP. The network would also have an incentive to discriminate in favor of its proprietary ISP in terms of quality of transmission (Economides 1998).

6.1.5 Infrastructure Fees to ISPs

Under open access, the network might charge an infrastructure fee to the ISPs in much the same way that the ISPs charge an access fee to content firms. The fee would introduce an element of bargaining between the networks and ISPs. If the bargaining power rested with the network, the relationships and incentives would be comparable to the ISP/content firm relationship modeled above. Just as an ISP has a demand effect and a profit effect that determine how much content it hosts, the network would have a demand effect and a profit effect determining how many ISPs it should offer.

The effects of infrastructure fees are complicated and deserve further study. They appear likely to reduce ISP entry, thus making open access more closely resemble closed access. On the other hand, infrastructure fees could increase network profits to the point that they favored open access. This makes the final outcome in terms of the free-entry numbers of networks, ISPs, and content firms uncertain.

6.2 The Course of the Open Access Debate

The open access debate has proceeded under the assumption that networks have very high fixed costs and are not very competitive with one another, while ISPs have very low fixed costs and are very competitive with one another. The model developed in this paper has shown that under these assumptions, open access produces much greater competition in the content industry, though probably with the tradeoff that there are fewer networks built.

The main point of the model is that the relative fixed costs and competitiveness of the network and ISP industries matter greatly to the success of open access. If the current assumptions do not hold in the future, then open access has much less positive effects on content competition, and can even lead to a less competitive content industry in extreme cases.

The ISP industry is changing rapidly as the Internet develops. This makes it very difficult to determine exactly what the future market structure of a stand-alone ISP industry will be. Since the success or failure of open access regulation depends on that hypothetical market structure, the FCC's "wait and see" policy seems justified. Once the parameters discussed above can be measured more accurately, the best policy will be more easily determined.

A Appendix

A.1 Symmetric Equilibrium

In this section, we show that there is a symmetric equilibrium when all NSPs simultaneously solve (4) (the proof is the same when all ISPs simultaneously solve (8)). We begin by determining what values of n_k are candidates for equilibrium. We then prove that the profit function is everywhere concave for these values.

To begin, we note that the derivative of (1) is

$$\frac{d\Phi_k(\mathbf{n})}{dn_k} = v'(n_k)\frac{\Phi_k(1-\Phi_k)}{\sigma^{NSP}}$$

Thus, the first order condition (5) can be written

$$\left(\frac{d}{dn_k}n_k\pi(n_k) - h\right)\Phi_k + (n_k(\pi(n_k)-h) + m^{NSP})v'(n_k)\frac{\Phi_k(1-\Phi_k)}{\sigma^{NSP}} = 0 \quad (14)$$

The first term of (14) is negative by *Decreasing Surplus*, so the second term must be positive for the equality to hold. The sign of the second term is determined by the sign of $n_k(\pi(n_k) - h) + m^{NSP}$, which is concave and eventually decreasing in n_k, again by *Decreasing Surplus*. Thus,

$$\exists \overline{n} \text{ s.t. } n_k(\pi(n_k)-h) + m^{NSP} \leq 0 \quad \forall\, n_k \geq \overline{n}$$

Then the solutions of (14) must fall in the interval $[0, \overline{n}]$.

The second order condition, based on the derivative of the left hand side of (14) is

$$\begin{aligned}&\left(\frac{d^2}{dn_k^2}n_k\pi(n_k) - h\right)\Phi_k + 2\left(\frac{d}{dn_k}n_k\pi(n_k) - h\right)v'(n_k)\frac{\Phi_k(1-\Phi_k)}{\sigma^{NSP}} + \\ &(n_k(\pi(n_k)-h) + m^{NSP})v''(n_k)\frac{\Phi_k(1-\Phi_k)}{\sigma^{NSP}} + \\ &(n_k(\pi(n_k)-h) + m^{NSP})(v'(n_k))^2\frac{(1-\Phi_k)(1-2\Phi_k)}{(\sigma^{NSP})^2} < 0\end{aligned}$$

The first and second terms of the SOC are negative by *Decreasing Surplus*. The third term is negative for concave v and for $n_k \in [0, \overline{n}]$. The fourth term is negative for the case of $\Phi_k > \frac{1}{2}$. For the case of $\Phi_k \leq \frac{1}{2}$, we note that if the sum of the third and fourth terms is negative, the entire second derivative is negative. Thus a sufficient condition for the SOC to hold is

$$(n_k(\pi(n_k)-h) + m^{NSP})\frac{\Phi_k(1-\Phi_k)}{\sigma^{NSP}}\left[v''(n_k)\Phi_k + (v'(n_k))^2\frac{1-2\Phi_k}{\sigma^{NSP}}\right] < 0 \quad (15)$$

The first terms of 15 are positive, so the inequality holds if the bracketed term is negative. Rearranging that term gives

$$\frac{1}{\sigma^{NSP}} + \left(\frac{v''(n_k)}{(v'(n_k))^2} - \frac{2}{\sigma^{NSP}} \right) \Phi_k \leq 0 \tag{16}$$

We now develop two conditions under which 16 holds. The first is very simple: if σ^{NSP} is sufficiently large, then 16 holds because the first term, which is positive, approaches 0.

An alternative condition for 16 to hold involves bounds on the function v. Suppose that v is bounded below by $v(0) = \underline{v}$ and bounded above by $\lim_{n\to\infty} v(n) = \overline{v}$. Then the lower bound on market share occurs when an NSP's subscribers receive $\underline{v}$ and would receive $\overline{v}$ from any of its competitors:

$$\underline{\Phi} = \frac{\exp\left(\frac{\underline{v} - m^{NSP} - t - s}{\sigma^{NSP}} \right)}{(K-1)\exp\left(\frac{\overline{v} - m^{NSP} - t - s}{\sigma^{NSP}} \right) + \exp\left(\frac{\underline{v} - m^{NSP} - t - s}{\sigma^{NSP}} \right)}$$

Suppose also that $r(n_k) = \frac{v''(n_k)}{(v'(n_k))^2}$ is bounded above by $\overline{r}$. Then (16) holds if

$$\frac{1}{\sigma^{NSP}} + \left(\overline{r} - \frac{2}{\sigma^{NSP}} \right) \underline{\Phi} \leq 0 \tag{17}$$

Any v such that $\overline{v}$ is sufficiently small, $\underline{v}$ is sufficiently large, and $\underline{r}$ is sufficiently large will satisfy this inequality. An example of such a function is

$$v(n_k) = A - B\exp(-\alpha n_k)$$

where $A = m^{NSP} + t + s + B$. For this function, $\underline{v} = A - B$, $\overline{v} = A$, and $\overline{r} = \frac{-1}{B}$. The smallest possible market share is $\underline{\Phi} = \frac{1}{(K-1)\exp(B)+1}$. Thus, for given σ^{NSP}, there is some value of B that ensures that (17) holds.

A.2 Comparative Statics

Property 1: $\dfrac{dn^{CA}(K)}{dK} > 0$.

Proof: Rearranging (5) and evaluating at the symmetric solution gives

$$\frac{K^{-1} - 1}{\sigma^{NSP}} = \frac{\frac{d}{dn} n^*\pi(n^*) - h}{v'(n^*)(n^*(\pi(n^*) - h) + m^{NSP})} \tag{18}$$

The derivative of the right hand side with respect to n^* is

$$\frac{\frac{d^2}{dn^2} n^*\pi(n^*)}{v'(n^*)(n^*(\pi(n^*) - h) + m^{NSP})} - \left(\frac{d}{dn} n^*\pi(n^*) - h \right) \left[\frac{v''(n^*)(n^*(\pi(n^*) - h) + m^{NSP}) + v'(n^*)\left(\frac{d}{dn} n^*\pi(n^*) - h\right)}{[v'(n^*)(n^*(\pi(n^*) - h) + m^{NSP})]^2} \right]$$

The denominators in both terms are positive, because v increases in n_k and because the networks would not enter unless they made a profit: $n^*(\pi(n^*) - h) + m^{NSP} > 0$. The numerator in the first term is negative by *Decreasing Surplus*. The numerator in the second term is negative because v is concave and because of *Decreasing Surplus*. The coefficient on the second term is also negative because of *Decreasing Surplus*. Putting these facts together, both terms are negative, so the right hand side of (18) is decreasing in n^*. Increasing K decreases the left hand side of (18); a corresponding decrease in the right hand side requires an increase in n^*.

Property 2: $\dfrac{dn^{CA}(K)}{d\sigma^{NSP}} < 0$.

Proof: Same as property 1, but now increasing σ^{NSP} decreases the LHS of (18).

Property 3: $\dfrac{dn^{CA}(K)}{dm^{NSP}} > 0$.

Proof: See the proof of property 1. In equation (18), a decrease in m^{NSP} decreases the right hand side (because the numerator is negative by *Decreasing Surplus*). It was shown in that proof that the right hand side of (18) is decreasing in n^*. Then if m^{NSP} decreases, n^* must increase to preserve the equality.

Property 4: $\dfrac{dn^{OA}(K)}{dm^{N}} = 0$.

Proof: m^N does not enter the equations for ISP and content firm equilibrium.

A.3 Comparison of Open to Closed Access

We make the comparison in two steps. First, consider what would happen if $L^{OA} = K^{CA}$; i.e. suppose open access did not result in additional entry of ISPs. Second, consider whether in fact $L^{OA} > K^{CA}$; i.e. whether open access does in fact result in more ISPs.

Definition: If $L^{OA} = K^{CA}$ there is *parity*. The *content ratio at parity* is $\frac{n^{OA}(K^{CA})}{n^{CA}(K^{CA})}$. If $\frac{n^{OA}(K^{CA})}{n^{CA}(K^{CA})} > 1$ then open access provides *greater content at parity*. If $\frac{n^{OA}(K^{CA})}{n^{CA}(K^{CA})} < 1$ then open access provides *less content at parity*.

Proposition 1: At parity, $\frac{n^{OA}(K^{CA})}{n^{CA}(K^{CA})}$ decreases in $\frac{\sigma^{ISP}}{\sigma^{NSP}}$, and increases in $\frac{m^{ISP}}{m^{NSP}}$.

Proof: $n^{CA}(K)$ is implicitly defined by (18). Likewise, $n^{OA}(L)$ is defined by

$$\frac{L^{-1} - 1}{\sigma^{ISP}} = \frac{\frac{d}{dn} n^*\pi(n^*) - h}{v'(n^*)(n^*(\pi(n^*) - h) + m^{ISP})} \tag{19}$$

The proof of Property 1 shows that the right hand sides of both (18) and (19) are decreasing in n^*. Fix $L^{OA} = K^{CA}$. Decreasing the σ term (in either equation) decreases the LHS; a corresponding decrease in the RHS requires a larger n^*. Since $\sigma^{ISP} < \sigma^{NSP}$, this effect produces a larger n^* under open access. Decreasing the subscription profit decreases the RHS (recall the RHS is negative because of *Decreasing Surplus*); a corresponding increase in the RHS requires a smaller n^*. Since $m^{ISP} < m^{NSP}$, n^* is smaller under open access and is decreasing in $m^{NSP} - m^{ISP}$.

Proposition 2: $\frac{L^{OA}}{K^{CA}}$ decreases in $\frac{n^{OA}(K^{CA})}{n^{CA}(K^{CA})}$ and decreases in $\frac{F^{ISP}}{F^{NSP}}$.

Proof: K^{CA} and L^{OA} are defined by

$$(n^{CA}(K)(\pi(n^{CA}(K)) - h) + m^{NSP})\frac{M}{K} = F^{NSP} \tag{20}$$

$$(n^{OA}(L)(\pi(n^{OA}(L)) - h) + m^{ISP})\frac{M}{L} = F^{ISP} \tag{21}$$

respectively. The LHS of (20) decreases in K, while LHS of (21) decreases in L. The greater the open access content at parity, the lower the access fees under open access, and hence the smaller the LHS of (21) relative to (20) for any $K = L$. If F^{NSP} and F^{ISP} were the same, this would require $L < K$. Actually, $F^{NSP} > F^{ISP}$, which, ceteris paribus, implies $L > K$. Which effect is stronger determines the outcome.

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