Computational Analysis of Practices that Threaten Network Neutrality in a Duopolistic Next-Generation Network Market*

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Abstract

Using a computational application that dynamically models competition between two Next-Generation Networks (NGN) this paper provides results that are potentially relevant to the important debate on network neutrality – specifically, the consequences of usage prices charged to content providers and the ability of platforms to block off-platform content. The dynamics of competition are modeled by calculating equilibrium prices in each of a number of time periods. We use the model to examine issues of relevance to the current telecommunications policy debate: (1) the impact of interconnection charges on total surplus and the distribution of surplus among market participants; and (2) the impact of platform usage charges for content providers or more explicit blocking of off-platform content on total surplus and the distribution of surplus. These results show that usage fees to content providers can to some extent be used to correct distortions in the setting of retail data prices for end user consumers. In addition, content blocking is shown to be potentially harmful to the interests of consumers though not for content providers. While keeping in mind that the reported results are relevant only to the specific model presented, it is hoped that the results of this analysis can be of use in guiding future policy decisions.

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1 Introduction

As Next-Generation Networks (NGN) begin to be deployed by telecommunications providers around the world, there is a need for new models of competition which can potentially incorporate realistic elements of the evolving technologies that support new services and different contractual relations between consumers, content providers and network operators. As demonstrated by the academic literature, competition models helped shape the regulatory agenda in crucial aspects such as interconnection between telephone networks; models have also been used to educate policymakers on the effects of proposed regulations or the implications of adopting certain regulatory decisions. In a previous paper (Beltran and Sharkey, 2008), we introduced a new model of competition between NGN networks, which we referred to as *platforms*. These platforms serve two basic types of users: content providers and end-user customers. The pricing structure used by the platforms is a two-part tariff, which includes a subscription charge and a usage charge. The original paper provided a partial, but not complete, characterization of the market equilibrium conditions when two NGN platforms compete.

Our extended research agenda on competing platforms seeks to illustrate several aspects that surface in the debate about rate structures, wholesale pricing of network termination and network neutrality in NGN. In order to do that, we extend the results obtained from market equilibrium conditions in a computational framework that facilitates direct computation of relevant equilibrium outcomes, as well as benchmark results such as consumer surplus, content provider profit and platform profit which can be used to evaluate the market outcomes. Using the same modeling framework we address a range of issues likely to occur in a set of competitive scenarios. The dynamics of competition are observed and measured at discrete periods of time, and this framework allows us to observe the evolution of key variables in response to strategic decisions by the platforms.

In this paper we use results from our computational model to get an insight into practices that threaten network neutrality in a duopolistic NGN market. The paper unfolds as follows: in section 2 we present the highlights of our model of competition between two NGN platforms. We report, in section 3, on results of our competitive scenarios: we first present a base case with default inputs, which helps illustrate the main assumptions about the model, and then we report on the role of competition intensity factors and other factors which determine the inter-temporal dynamics of market competition. Finally, we consider the effects of two potential threats to network neutrality. Section 4 concludes.

2 A Model of Competition between Two Next Generation Platforms

In this section we briefly review the model of Beltran and Sharkey (2008), which is used as the basis for the computational results that follow. We regard a network operator as a platform that attracts different types of consumers who connect to the network, purchasing services from the platform. The market is two-sided in the sense that platforms compete for both retail consumer subscribers and for content providers who serve the consumers.[1] A more detailed description of each of the model components is presented below.

2.1 Demand and Utility Functions

Two platforms, platform 1 and platform 2, compete in a market that has two types of consumers: content providers and end-users, and two services: voice and data. At time zero, platform 1 (the incumbent) typically has a larger market share than platform 2 (the entrant or rival). The platforms compete under a two-part tariff scheme. Platform *i*'s initial market shares in those markets are given by $\alpha_i(0)$ and $\beta_i(0)$ for voice and data, respectively. Platforms charge prices in accordance to the following notation: (for *i* or *j* = 1, 2)[2]

p_{ij} , price to consumers of platform i for voice traffic with consumers on platform j

q_{ij} , price to consumers of platform i for data traffic with a content provider on platform j

r_{ij} , price to content providers on platform i for data traffic with a consumer on platform j

m_i , subscription price for consumers on platform i

n_i , subscription price for content providers on platform i

Competition occurs over multiple periods. Market shares are expected to change in every period in which the indirect utility of consumers, or the profit of content providers differs between the two competing firms at their current prices. When one of the firms is an entrant, the interpretation is that entry (or potentially exit) occurs in early periods as the firms dynamically adjust their prices. Market shares continue to adjust up to the point at which every consumer and every content provider is indifferent between the firms. Beyond this point, further entry or exit ceases. Competition then enters a stable phase in which the market for consumers and content providers is segmented in much the same way as in a more traditional product differentiation model. Initial market shares are arbitrarily determined in the default input assumptions.

Consumers derive utility from sending messages, x_{Voice}, to other consumers (on either platform) and from receiving content, x_{Data}, from network content providers (on either platform). The utility from content is assumed to depend on the total content made available to a platform as well as the number of units of data services consumed. Consumer utility is assumed to be separable between voice messages and data services. We assume individual consumer's demand functions for voice and data services, $x_{\text{Voice}}(p) = a_{Voice} - b_{Voice}\, p$ and $x_{\text{Data}}(q, Content) = Content * (a_{Data} - b_{Data}\, q)$. Content is supplied in an increasing marginal cost production

[1] One should think of content providers as "content distributors" and not necessarily as "content creators." That is, we specifically model a content provider as a firm engaged in the delivery of data services to end user consumers through a connection to a NGN. Revenues and profits for content providers are assumed to depend entirely on advertising revenues, which in turn depend on the number of end user consumers who view the provided content. As will be shown below, end user consumer demands depend both on pricing decisions by platforms for consumer data services and content provider decisions on the quality of the content that they choose to provide.

[2] We assume that if content providers are charged a usage price, it applies only when the provider terminates data traffic on the platform imposing the charge.

environment, with cost function given by $TC(Content) = ProviderFC + ProviderVC\frac{Content^2}{2}$. Content provision is competitively supplied, which means that a content provider will supply content up to the level at which price is equal to marginal cost, given by *ProviderVC*.

Content providers earn revenues from advertising. Advertising revenue (*AdRev*) is assumed to be equal to a constant fraction, *AdRevMultiplier*, of total consumer utility (*ContentUtility*), per unit of data output. When the platform's customer market share is α, one unit of content is supplied, and, customer data price is equal to *q* it follows that

$$AdRev(q,\alpha) = \alpha\ AdRevMultiplier\ ContentUtility(x_{Data}, 1) \quad (1)$$

Content providers may pay usage fees to platform operators. Total fees paid by a provider offering one unit of content on a platform with customer market share α, where the provider charge per data minute is equal to *r* and customer charge per data minute is equal to *q*, are given as follows:

$$UsageFee(q,r,\alpha) = r\alpha\, x_{Data}(q,1) \quad (2)$$

Both, advertising revenues and usage fees depend on the market share of end-user consumers on each platform. Since the variable *Content* enters as a multiplicative shift parameter in the consumer demand functions x_{Data}, an increase in content increases both advertising revenues and provider usage fees. As a function of relevant platform prices and market shares, using (1) and (2), content supply of a provider on platform *i* is given by

$$\begin{aligned} ContentSupply(q_{1i}, q_{2i}, r_{1i}, r_{2i}, \alpha_1, \alpha_2) = \frac{1}{ProviderVC}\big[& AdRev(q_{1i},\alpha_1) + AdRev(q_{2i},\alpha_2) - \\ & UsageFee(q_{1i}, r_{1i}, \alpha_1) - UsageFee(q_{2i}, r_{2i}, \alpha_2)\big] \end{aligned} \quad (3)$$

In the current framework, a consumer's fixed utility and content provider's fixed profit depend on a particular platform's market share. *ConsumerFixedUtility* represents the value of a communications network that is not captured by voice and data usage (e.g. the option value of receiving calls, making emergency calls, or having access to the internet). A consumer may value a platform having many content providers more highly because of higher quality data transfers or possible blocking of content from providers on another platform. The *ConsumerExternality* function captures these effects. *ProviderExternality* represents the value that suppliers have to be on the same network with consumers plus the potentially negative value that suppliers have to share the same network with other suppliers. The following functions represent the externality functions, where all parameters C_{X1}, C_{X2}, P_{X1} and P_{X2} are assumed to be nonnegative and $P_{X2} < 1$. Values near zero represent minimal externalities.

$$ConsumerExternality(\alpha_i, \beta_i) = \frac{(1 + C_{X1}\alpha_i)(1 + C_{X2}\beta_i)}{(1 + C_{X1})(1 + C_{X2})} ConsumerFixedUtility$$

(4)

$$ProviderExternality(\alpha_i, \beta_i) = \frac{(1 + P_{X1}\alpha_i)(1 - P_{X2}\beta_i)}{(1 + P_{x1})(1 - P_{X2})} ProviderFixedUtility$$

The consumer indirect utility $V_i(.)$ and provider profit functions $P_i(.)$ are used to determine dynamic market share functions and to define consumer and content provider surplus. These functions incorporate a "balanced traffic" assumption, which means that a given consumer on either platform is equally likely to place a voice call to any other consumer on either platform, and is equally likely to request a data transfer from any other content provider on either platform. Indirect utility for a consumer on platform *i* facing usage prices p_{i1} and p_{i2} for voice traffic and q_{i1} and q_{i2} for data traffic from platforms 1 and 2 respectively, and a subscription price m_i is given as follows.

$$\begin{aligned} V_i(p_{i1}, p_{i2}, q_{i1}, q_{i2}, m_i, t) &= ConsumerExternality[\alpha_i(t-1), \beta_i(t-1)] + \\ &\alpha_1(t-1) VoiceUtility(x_{Voice}(p_{i1})) + \alpha_2(t-1) VoiceUtility(x_{Voice}(p_{i2})) + \\ &\beta_1(t-1)\ ContentUtility[x_{Data}(q_{i1}, Content_1(t-1)), Content_1(t-1)] + \\ &\beta_2(t-1)\ ContentUtility[x_{Data}(q_{i2}, Content_2(t-1)), Content_2(t-1)] - \\ &\alpha_1(t-1)\ p_{i1} x_{Voice}(p_{i1}) - \alpha_2(t-1)\ p_{i2} x_{Voice}(p_{i2}) - \beta_1(t-1)\ q_{i1}\ x_{Data}(q_{i1}, Content_1(t-1)) - \\ &\beta_2(t-1)\ q_{i2}\ x_{Data}(q_{i2}, Content_2(t-1)) - m_i \end{aligned} \quad (5)$$

Note that both the content functions and the market share functions are defined with a one period lag. As a simplification in notation, we will write $V_i(t)$ to represent $V_i(p_{i1}, p_{i2}, q_{i1}, q_{i2}, m_i, t)$.

Profit functions for a content provider connected to either operator are functions of consumer usage prices and provider prices for on-net and off-net data service. By convention, we assume that content providers benefit from both on-net and (potentially from) off-net advertising revenues, and are charged only when they deliver content to a customer on a particular platform. Again, dropping the dependence of the provider profit function on prices (in this case q_{i1}, q_{i2}, r_{i1}, r_{i2}, n_i) for notational convenience, we can express the profit function for a provider connected to platform *i* as:

$$\begin{aligned} P_i(t) = ProviderExternality[\alpha_i(t-1), \beta_i(t-1)] + Content_i(t-1) \{ &AdRev(q_{1i}, \alpha_1(t-1)) + \\ &AdRev(q_{2i}, \alpha_2(t-1)) - UsageFee(q_{1i}, r_{1i}, \alpha_1(t-1)) - \\ &UsageFee(q_{2i}, r_{2i}, \alpha_2(t-1)) \} - n_i - TC(Content_i(t-1)) \end{aligned} \quad (6)$$

2.2. Market Shares

$\alpha_i(t)$ and $\beta_i(t)$ represent platform *i*'s market share for consumers and content providers in any period *t*. Market shares are arbitrarily determined at the start (period 0) and updated for every subsequent period. Current market share, at time t, depends on the differential utility or profit that a consumer or provider can expect on each platform, as well as the market share at t–1 and the competitive intensity parameters, Z_C and Z_P, which measure a consumer's loyalty to a platform. A higher value of Z_C may indicate that the platform is more able to retain its customers through some type of locked-in service offers; it also may signal that customers feel some kind of loyalty to the platform so that they become "hard to switch". A higher value of the provider intensity parameter, Z_P, may similarly indicate that providers are less likely to switch to the other platform due to the existence of already convenient commercial agreements between providers and the platform.

We assume that customer loyalty is a value that is uniformly distributed on an interval [0, Z_C] for end-users and [0, Z_P] for content providers. A fraction of end-user consumers and content providers are assumed to switch from platform 2 to platform 1 whenever the difference between the utility (profit) that they would derive from platform 2 is larger than the utility they currently derive from platform 1. The fraction of consumers or providers who choose to switch increases as the difference in utility or profit increases. Consequently, market shares for platform 1 are given by

$$\begin{aligned} \alpha_1(t) &= \alpha_1(t-1) + \frac{V_1(t) - V_2(t)}{Z_C} \\ \beta_1(t) &= \beta_1(t-1) + \frac{P_1(t) - P_2(t)}{Z_P} \end{aligned} \tag{7}$$

We assume that all consumers and content providers choose to participate in the market by choosing either platform 1 or platform 2. Accordingly, $\alpha_2(t) = 1 - \alpha_1(t)$ and $\beta_2(t) = 1 - \beta_1(t)$. Since the market share functions $\alpha_i(t)$ depends on consumer utility functions V_1 and V_2, they are necessarily a function of the entire set of prices p_{ij}, q_{ij}, r_{ij}, m_i, and n_i (i, j = 1,2) as well as t. Each $\beta_i(t)$ is a function of the same set of prices in each period t.

Equations (7) describe an important property of the current model, and the way in which it differs from a traditional product differentiation model. In a product differentiation approach, consumers are assumed to have continuously varying, but fixed, preferences for each of two firms. In the classic Hotelling model, consumers are located along a road segment with identical firms at each end point. Customers care about transportation costs, and competition between the firms occurs in a single period as the firms set prices in order to segment the market. In equilibrium, the marginal consumer, and only this consumer, is indifferent between patronizing one firm or the other. In the present approach, competition occurs over multiple periods. All consumers are identical in all respects other than consumer loyalty. As equations (7) show, market shares are expected to change in every period in which the indirect utility of consumers, or the profit of content providers differs between the two competing firms at their current prices. When one of the firms is an entrant, the interpretation is that entry (or potentially exit) occurs in early periods as the firms dynamically adjust their prices. Market shares continue to adjust up to the point at which every consumer and every content provider is indifferent between the firms. Beyond this point, further entry or exit ceases. Competition then enters a stable phase in which the market for consumers and content providers is segmented in much the same way as in a product differentiation model.

2.2 Traffic and Costs

From a platform's viewpoint, both voice and data traffic can be on-net, off-net or incoming. On-net traffic is voice or data traffic originating and terminating on a single platform. Off-net traffic is voice traffic that originates from an on-platform subscriber and terminates with another platform's subscriber, and data traffic requested by an on-platform subscriber from a content provider on another platform. Incoming traffic is voice traffic that originates from a subscriber on another platform and terminates with an on-platform subscriber, and data traffic requested by a customer from another platform to an on-platform content provider. The general principle to be used in the calculation of traffic patterns is that whenever an end-user initiates any communication, the receiving consumer (end-user or content provider) may be any other consumer with equal probability, regardless of the platform he or she is connected to. This "balanced traffic" assumption has been used by Laffont *et al.* (1998a, 1998b) and virtually all of the subsequent literature on network competition.

Platform operators incur both fixed and variable costs. Variable costs on platform i for the origination of voice and data traffic (including transport) destined to the other platform are given by c_{i1} and d_{i1}. For incoming traffic, the marginal costs of terminating voice and data traffic (including transport) are given by c_{i2} and d_{i2}. We assume that the costs of customer requests for data traffic (origination and termination) are negligible (i.e. for data traffic $c_{i1} = c_{i2} = 0$). Marginal "on-net" costs for voice and data traffic are given respectively by $c_{13} = c_{11} + c_{12}$ and $d_{13} = d_{11} + d_{12}$. Fixed costs of network operators are given by f_{Ci}, representing the fixed cost of attaching an additional voice subscriber to platform i, and f_P, representing the fixed cost of attaching an additional content provider to either platform.

Platform operators also incur costs in the form of access charges for terminating calls which their own subscribers originate, and which terminate on the opposing network. In the case of voice calls, access charges are traditionally set by a regulator, and in our notation these are denoted by $ta_{1\text{Voice}}$ and $ta_{2\text{Voice}}$ respectively for platforms 1 and 2. For data services, termination charges between networks are traditionally set by negotiations between platforms. Under peering arrangements, these charges are set equal to zero, while under transit arrangements a positive termination charges is agreed upon by both platforms. In either case, we assume that data termination charges are set independently of the competitive dynamics which determine all retail prices charged directly to consumers or content providers. The wholesale termination charges for data services on platform i will be denoted by $ta_{i\text{Data}}$ and $ta_{i\text{Data}}$.

The profit function for platform *i* is therefore given as follows.

$$
\begin{aligned}
\pi_{\mathrm{i}}(t) = {} & \alpha_i(t)^2 \; x_{Voice}(p_{ij})(p_{ij} - c_{i3}) + \\
& \alpha_i(t)\, \beta_i(t)\, x_{Data}(q_{ij}, Content_{\mathrm{i}}(t-1))(q_{ij} + r_{ij} - d_{i3}) + \\
& \alpha_i(t)\, \alpha_j(t)\, x_{Voice}(p_{ij})(p_{ij} - c_{i1} - ta_{jVoice}) + \\
& \alpha_i(t)\, \beta_j(t)\, x_{Data}(q_{ij}, Content_{\mathrm{j}}(t-1))(q_{ij} + r_{ij} - d_{i2} + ta_{iData}) + \\
& \alpha_i(t)\, \alpha_j(t)\, x_{Voice}(p_{ji})(ta_{iVoice} - c_{i2}) + \\
& \alpha_j(t)\, \beta_i(t)\, x_{Data}(q_{ji}, Content_{\mathrm{i}}(t-1))(-d_{i1} - ta_{jData}) + \\
& \alpha_i(t)(m_i - f_{Ci}) + \beta_i(t)(n_i - f_P)
\end{aligned}
\tag{8}
$$

2.3 Equilibrium Conditions

Platforms are assumed to compete non-cooperatively in every time period using subsets of the full set of retail prices specified above. Nash equilibria can then be determined by solving modified versions of the following set of first order conditions, keeping in mind the dependence of each profit function, π_1 and π_2 for platforms 1 and 2 respectively, on the full set of prices:

$$
\frac{\partial \pi_i(t)}{\partial p_{ij}} = 0; \quad \frac{\partial \pi_i(t)}{\partial q_{ij}} = 0; \quad \frac{\partial \pi_i(t)}{\partial r_{ij}} = 0; \quad \frac{\partial \pi_i(t)}{\partial m_i} = 0; \quad \frac{\partial \pi_i(t)}{\partial n_i} = 0; \quad i, j = 1, 2 \tag{9}
$$

When platforms do not compete using the full set of price variables described above the equilibrium conditions (9) are modified in various ways. For example, subscription prices and usage prices for content providers may or may not be available to platform operators; platforms may or may not discriminate between on-net and off-net data pricing for either consumers or content providers; and platforms may or may not charge off-platform content providers. Therefore, one or more constraints are typically imposed and the constrained system is then solved. For example, when price discrimination is not possible, the constraint $p_{ij} = p_{ii}$ replaces the first order condition $\frac{\partial \pi_i(t)}{\partial p_{ij}} = 0$. Also, in Beltran and Sharkey (2008) it was shown that a full solution to equations (9) is not possible when platform operators are able to charge usage fees to content providers without constraint. In such cases, we assume that when usage prices r_{ij} are feasible, they are determined outside of the competitive process (e.g. by negotiation between the platforms or by regulatory constraint) and that the same prices are charged to on-platform and off-platform content providers; in other words, $r_{\mathrm{i1}} = r_{\mathrm{i2}} = r_{\mathrm{i}}^*$.

When platforms are able to block off-platform content we assume that consumers on a given platform are equally likely to select a content provider on the same platform, but select an off-platform provider with zero probability. Equations (5) and (6) for consumer indirect utility and content provider profit respectively, are changed accordingly. When off-platform data services are not available to consumers on each platform, platforms do not compete in setting either consumer prices or content provider prices for off-platform content.

Therefore the first order conditions, which are valid assuming that platforms do not price discriminate, are modified as follows when there is content blocking:

$$\begin{array}{llll} \dfrac{\partial \pi_1(t)}{\partial p_{11}} = 0 & p_{12} = p_{11} & \dfrac{\partial \pi_2(t)}{\partial p_{22}} = 0 & p_{21} = p_{22} \\ \dfrac{\partial \pi_1(t)}{\partial q_{11}} = 0 & \dfrac{\partial \pi_2(t)}{\partial q_{22}} = 0 & r_{11} = r_1^* & r_{22} = r_2^* \\ \dfrac{\partial \pi_1(t)}{\partial m_1} = 0 & \dfrac{\partial \pi_1(t)}{\partial n_1} = 0 & \dfrac{\partial \pi_2(t)}{\partial m_2} = 0 & \dfrac{\partial \pi_2(t)}{\partial n_2} = 0 \end{array} \qquad (10)$$

In a closely related model of network competition, Laffont *et al*. (1998a, 1998b) demonstrate that under certain conditions a unique symmetric equilibrium exists both with and without price discrimination. The sufficient conditions in both results require that either (1) terminating access prices are close to marginal cost, or (2) competition is sufficiently weak, which in the product differentiation model assumed implies that the networks are sufficiently poor substitutes. De Bijl and Peitz (2002) extend the above results to a model like the present one in which firms are symmetric, but compete in an environment with customer switching costs. In the present context, equilibrium during any period t requires that the following conditions hold:

(C1): There exist price variables p_{ij}, q_{ij}, m_i, and n_i such that the first order conditions are satisfied,

(C2): $0 < \alpha_i(t)$ and $0 < \beta_i(t)$ for $i = 1, 2$, and

(C3): $\pi_i(p_{i1}, p_{i2}, q_{i1}, q_{i2}, r_i, m_i, n_i) \geq 0$ for $i = 1, 2$.

Condition (C1) is a consequence of the fact that we have not imposed inequality constraints on any of the strategic pricing variables. Condition (C2) must be satisfied because the market share functions do not explicitly constrain either firm's market share to be between zero and one. If condition (C3), non-negativity of profits, does not hold, then one of the platforms would prefer to exit the market (even though the model does not formally allow a platform to exit). The existence of an equilibrium in any period t depends on the initial market shares $\alpha_i(t–1)$ and $\beta_i(t–1)$ as well as the values of other input parameters.

In Beltran and Sharkey (2008) analytic solutions, on a period by period basis, to the appropriately constrained first order conditions (9) or (10) and the equilibrium conditions (C1) – (C3) were derived. These are repeated in Propositions 1 – 3 below.

***Proposition* 1:** Suppose that platforms do not price discriminate, and that they are able to charge for both on-platform and off-platform content using non-competitively determined usage prices r_1 and r_2 for content providers on platforms 1 and 2 respectively. In any solution to the set of first order conditions (9), usage prices for consumer voice are equal to perceived marginal cost for voice service, and usage prices for consumer data *plus* usage prices for content providers are equal to perceived marginal cost for data service. That is,

$$p_{11}(t) = p_{12}(t) = \alpha_1(t)\, c_{13} + \alpha_2(t)\left(c_{11} + ta_{2Voice}\right)$$
$$p_{21}(t) = p_{22}(t) = \alpha_2(t)\, c_{23} + \alpha_1(t)\left(c_{21} + ta_{1Voice}\right) \tag{11}$$

and

$$q_{11}(t) + r_1 = q_{12}(t) + r_1 = \beta_1(t)\, d_{13} + \beta_2(t)\left(d_{12} - ta_{1Data}\right)$$
$$q_{21}(t) + r_2 = q_{22}(t) + r_2 = \beta_2(t)\, d_{23} + \beta_1(t)\left(d_{22} - ta_{2Data}\right) \tag{12}$$

□.

***Proposition* 2:** Suppose that platforms are able to price discriminate, and that they are able to charge for both on-platform and off-platform content using non-competitively determined usage prices r_1 and r_2 for content providers on platforms 1 and 2 respectively.

(i) In any solution to the set of first order conditions (9), consumer voice prices are equal to marginal costs (including termination charges) on platform *i* for all *t* such that $\alpha_i(t) = \alpha_i(t–1) > 0$. That is,

$$p_{11}(t) = c_{13} \qquad p_{12}(t) = c_{11} + ta_{2Voice}$$
$$p_{22}(t) = c_{23} \qquad p_{21}(t) = c_{21} + ta_{1Voice} \tag{13}$$

(ii) If platforms are able to charge fixed fees to content providers, there exists a solution[3] to (9) such that if $\beta_i(t) = \beta_i(t–1) > 0$,

$$q_{11}(t) = \frac{d_{13}}{1 + AdRevMultiplier}$$
$$q_{22}(t) = \frac{d_{23}}{1 + AdRevMultiplier} \tag{14}$$

$$q_{12}(t) = \frac{r_1 + \beta_2(t)\left(ta_{1Data} - d_{12}\right)}{\beta_1(t)\, AdRevMultiplier - \beta_2(t)}$$
$$q_{21}(t) = \frac{r_2 + \beta_1(t)\left(ta_{2Data} - d_{22}\right)}{\beta_2(t)\, AdRevMultiplier - \beta_1(t)} \tag{15}$$

□.

***Proposition* 3:** Suppose that platforms are able to block content from off-platform content providers, and that usage prices for on-platform content providers are determined outside of the competitive model.

(i) In any solution to (9), consumer voice prices are given by (11) when there is no price discrimination in consumer voice prices, and by (13) when price discrimination is possible.

[3] In contrast to Proposition 1, Proposition 2 does not guarantee uniqueness of the consumer data prices q_{ij}. In addition, we have not yet been able to solve for equilibrium usage charges for consumer data services when platforms do not charge fixed fees to content providers.

(ii) When $\alpha_i(t) = \alpha_i(t–1) > 0$ and $\beta_i(t) = \beta_i(t–1) > 0$ (with or without price discrimination in consumer voice prices), and fixed fees to content providers are feasible, consumer data prices are given as follows:

$$q_{11}(t) = \frac{d_{13} - r_1\ \beta_2(t)}{1 + AdRevMultiplier\ \beta_1(t)}$$
$$q_{22}(t) = \frac{d_{23} - r_2\ \beta_1(t)}{1 + AdRevMultiplier\ \beta_2(t)} \tag{16}$$

(iii) When $\alpha_i(t) = \alpha_i(t–1) > 0$ and $\beta_i(t) = \beta_i(t–1) > 0$ (with or without price discrimination in consumer voice prices), and fixed fees to content providers are not feasible, consumer data prices are given as follows:

$$q_{11}(t) = \frac{d_{13} - r_1\left(1 + \frac{f_P}{Z_P}\right)}{1 - AdRevMultiplier\ \frac{f_P}{Z_P}}$$
$$q_{22}(t) = \frac{d_{23} - r_2\left(1 + \frac{f_P}{Z_P}\right)}{1 - AdRevMultiplier\ \frac{f_P}{Z_P}} \tag{17}$$

□.

Since the results in the following sections are based on computational simulations, it is important to describe the methods used to evaluate the results that we obtain. Equations (11) through (17) allow us to directly compute consumer usage prices. We are also able to obtain analytical solutions for equilibrium values of subscription charges as functions of market shares in periods t and t – 1. It remains only to compute equilibrium values of market shares $\alpha_i(t)$ and $\beta_i(t)$ in each period t given assumed starting values $\alpha_i(0)$ and $\beta_i(0)$, and in most cases we are able to do this using numerical methods. For computations involving price discrimination, we have so far been unable to obtain unique solutions for equilibrium market shares. In these cases, a full numerical solution to the equilibrium conditions (9) is obtained by specifying an arbitrary set of initial starting values for all price variables, market shares and content levels in period 0. Using Newton's method, a solution is obtained for period 1, and these values are used as starting values for an identical optimization in period 2. The process continues for as many periods as desired.

In the following section, we will report results for a set of competitive simulations, each of which will run for 20 periods. Summary outputs for each simulation will be reported as follows:

$$\text{Consumer Surplus} = \sum_{t=1}^{20} \delta^{t} \left[\alpha_1(t) V_1(t) + \alpha_2(t) V_2(t) \right]$$

$$\text{Provider Profit} = \sum_{t=1}^{20} \delta^{t} \left[\alpha_1(t) P_1(t) + \alpha_2(t) P_2(t) \right]$$

$$\text{Platform Profit} = \sum_{t=1}^{20} \delta^{t} \left[\pi_1(t) + \pi_2(t) \right]$$

Total Surplus = Consumer Surplus + Provider Profit + Platform Profit

3 Competitive Scenarios

3.1 Representative Outputs for a Base Case with Default Inputs

We first report a full set of outputs for a base case using a default set of input prices and parameters which are documented in the Appendix. We assume that platforms are able to set both a usage fee and a fixed subscription fee to customer subscribers on each platform. In the base case, platforms charge a fixed fee but no usage fee to content providers. The default demand function for voice traffic is similar to the demand specification used in De Bijl and Peitz, (2002) who argued that their specification roughly approximates the demand for voice traffic in the Netherlands. The default inputs also roughly correspond to access and transit pricing agreements that are in place today in some markets. That is, the terminating access charge for voice traffic (equal to 2) is assumed to be greater than the marginal cost of voice termination (equal to 1), while the terminating access charge for data traffic is assumed to be equal to zero (where marginal cost is equal to 2).

Figures 1 – 4 illustrate the dynamic paths of relevant price, market share and surplus functions over the time horizon studied, which in all cases we assume is equal to 20 periods. In the default inputs, a period is assumed to consist of a single calendar quarter, which is based on an assumption that network platforms compete by adjusting prices four times in every calendar year.[4] The simulations therefore show the dynamic effects of competition over a five-year time horizon.

[4] The discount rate used to summarize total surplus and profit results in all future computations is appropriately adjusted for the length of period. In the default set of inputs, we assume an annual interest rate of 10%, which implies a per period discount factor of 0.976

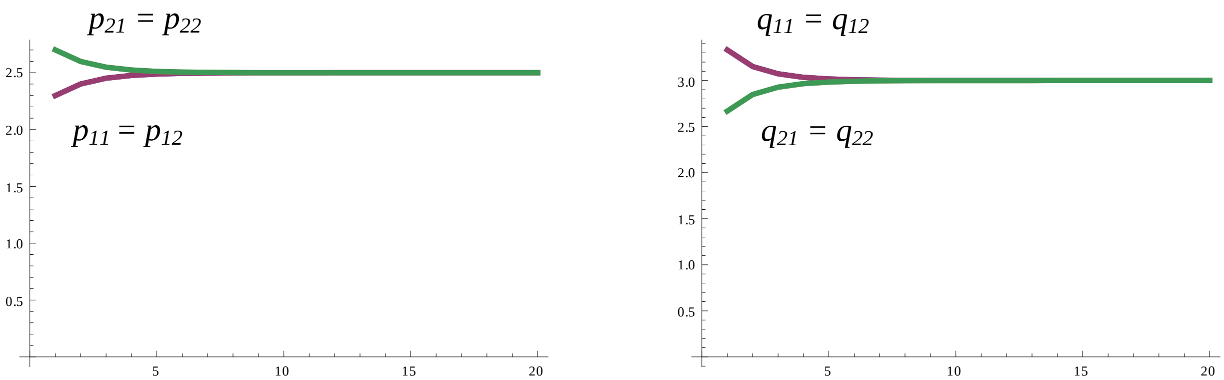

Figure 1: Consumer Voice and Data Prices

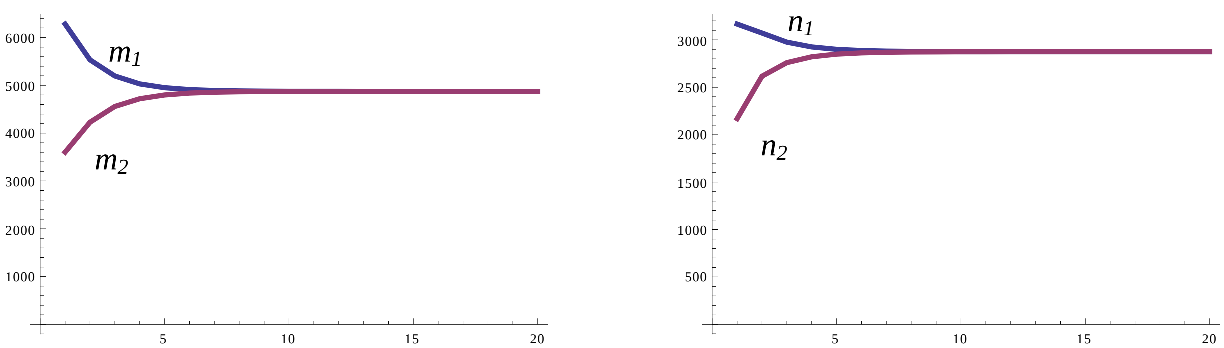

Figure 2: Consumer and Content Provider Subscription Fees

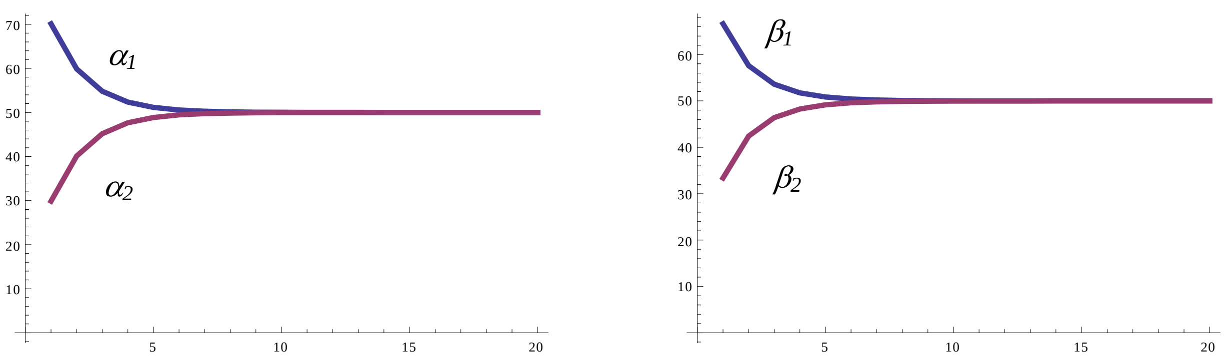

Figure 3: Market Shares in Consumer and Content Provider Markets

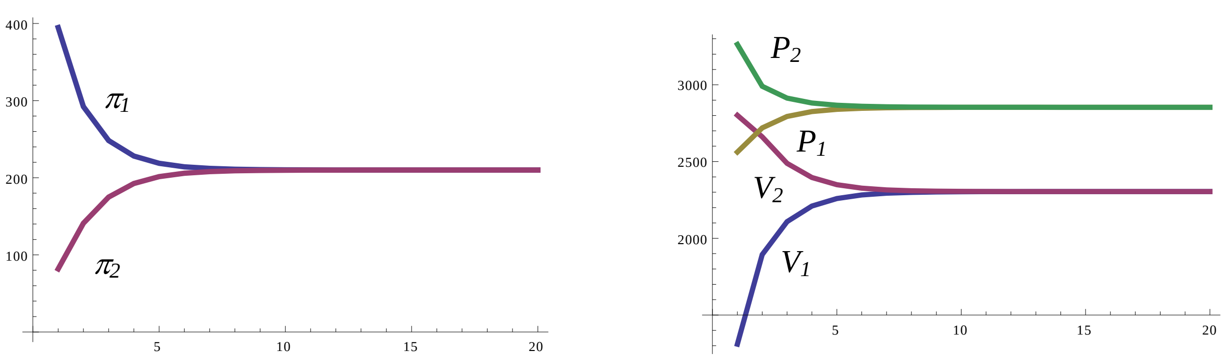

Figure 4: Operator Profits and Surplus by Type

Figures 1 – 4 demonstrate that platform prices converge to equal values after approximately 7 periods under the default assumptions. Correspondingly, market shares converge to equal 50% levels in both customer and content provider sides of the market, while platform profits and customer and provider surplus follow a similar path. In later sections, we will present selected dynamic results only when they differ significantly from our base case. In many cases, it will be sufficient to present summary outputs consisting of total surplus or profit over the entire horizon and the final period prices or market shares obtained.

While most of our results will be concerned with the dynamic model of network competition, as presented above, it is also useful to also consider two relevant benchmarks against which future results can be compared. To define the monopoly benchmark, we assume that the entire market is served by a single firm (platform 1) for each of the 20 periods. All traffic is by definition on-net, and we assume that the monopoly firm sets both usage prices and fixed fees in every period so as to maximize platform profits, subject to the constraints that consumers and content providers will choose to participate in the market – i.e. $V_1(t) \geq 0$ and $P_1(t) \geq 0$ for every t. If the monopoly is regulated, then under the default input assumptions, a decrease in consumer or content provider subscription fees can result in an efficient redistribution of total surplus in favor of consumers or content providers.

To define a "Ramsey" benchmark, we assume that two firms equally share the market in every time period, and that all prices are set so as to maximize total surplus, subject to the constraints that consumers, content providers and platforms are all willing to participate – i.e. $V_i(t) \geq 0$, $P_i(t) \geq 0$ and $\pi_i(t) \geq 0$ for $i = 1$ and 2. As in the monopoly example, consumer or content provider surplus can be converted to platform profits under appropriate regulation (or relaxed regulation).[5] For voice services, Ramsey benchmark prices are defined in the following result.

***Proposition 4*:** When platforms do not price discriminate, surplus maximizing prices for voice are defined as follows:

$$\begin{aligned} p_{11}^*(t) = p_{12}^*(t) &= \frac{c_{11} + c_{22} + c_{13}}{2} \\ p_{22}^*(t) = p_{21}^*(t) &= \frac{c_{21} + c_{12} + c_{23}}{2} \end{aligned} \tag{18}$$

When platforms are able to price discriminate, surplus maximizing prices are given by

$$\begin{aligned} p_{11}^*(t) &= c_{13} \qquad p_{12}^*(t) = c_{11} + c_{22} \\ p_{22}^*(t) &= c_{23} \qquad p_{21}^*(t) = c_{21} + c_{12} \end{aligned} \tag{19}$$

[5] Since platforms are able to charge fixed subscription fees to consumers in all cases, and to content providers in some of our scenarios, there is, in general, no unique set of prices (including subscription fees) that will maximize total surplus. The Ramsey benchmark results reported below therefore assume that platform profits are constrained to be exactly equal to zero.

Optimal prices for data services depend on the profitability of the content provision market in addition to the marginal costs of origination and termination incurred by platforms. Under the default input assumptions, benchmark data prices are equal to 1.83, which is significantly less than the marginal platform costs (d_{i3} = 4 for on-net data traffic and d_{i2} = 2 for off-net traffic). This result holds because both customer subscribers and content providers benefit from an increase in data traffic, while customer subscribers alone determine the volume of that traffic. It is therefore efficient to price data services below marginal cost, and recover the incremental lost profits through higher fixed charges for customers, or (if possible) for content providers. Profitability of the content provision market is determined in our model by the input parameters *AdRevMultiplier* and *ProviderVariableCost*.

Table 1 compares competitive duopoly performance to both monopoly and Ramsey benchmark results assuming the default input assumptions. While the distribution of total surplus among consumers, content providers and platforms is not uniquely defined under the monopoly and Ramsey benchmarks, the competitive outcomes define a unique distribution of surplus among the relevant parties because platforms compete for subscribers by setting subscription fees after retail consumer prices are determined.

Table 1: Benchmark Surplus and Profit with Default Inputs

	Total Surplus	Consumer Surplus	Provider Profit	Platform Profit
Monopoly	14784	0	0	14784
Ramsey	13391	5926	7465	0
Competition	13112	2859	3584	6669

Since the consumer and content provider externality factors in the current model enter as multiples of market shares, and because customers generally prefer to subscribe to a network with a large number of other consumers and providers, monopoly has an inherent advantage when externality factors are positive.[6] Hence total surplus under monopoly is higher under the default input assumptions than under regulated or competitive duopoly assumptions. Table 2 reports similar results under the assumption that externality factors are equal to zero.

Table 2: Benchmark Surplus and Profit

(Default inputs with zero externality parameters)

	Total Surplus	Consumer Surplus	Provider Profit	Platform Profit
Monopoly	14784	0	0	14784
Ramsey	14784	7829	6955	0
Competition	14473	4054	3791	6628

[6] Since the externality factors assumed in the default input assumptions have not been chosen on the basis of any empirical analysis, it is not appropriate to draw conclusions about the desirability of competition versus monopoly on this basis.

3.2 Determinants of Entry and Exit

In this section, we report on a set of simulations that document the role of the competition intensity factors and other model parameters that determine the inter-temporal dynamics of market competition.

3.2.1 Competition Intensity Factors

Beltran and Sharkey (2008) establish that entry is, in many cases, feasible whenever the competition intensity factors Z_C and Z_P are large enough. These propositions do not, however, reveal what might happen if Z_C and Z_P are not large. Figure 5 below reveals that as competition becomes more intense (Z_C and Z_P decrease from their assumed default values), the rate of entry by firm 2 initially slows in both the consumer and content provider markets.

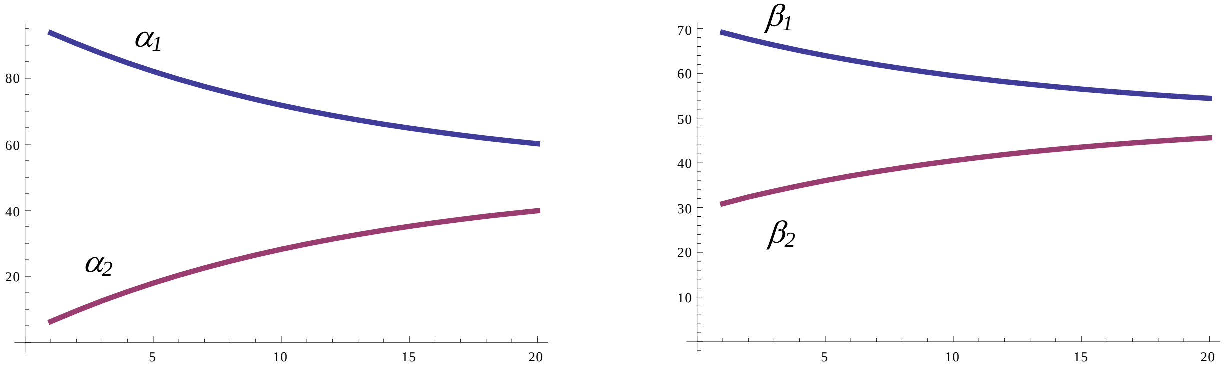

Figure 5: Market Shares in Consumer and Content Provider Markets
(Default inputs with $Z_C = Z_P = 1700$)

In section 3.3.3 below we will show termination charges interact with the competition intensity factors in an important way in determining the prospects for entry or exit of a smaller rival platform.

3.2.2 Rate Structure and Externality Factors

Suppose that platform operators are not able to charge a subscription fee to content providers. In this case, the dynamics of competition change substantially. Market shares are now less responsive to competition, platform profits are significantly lower, and not surprisingly, provider profits are higher. Figure 6 shows some of the competitive dynamics in a simulation using the default inputs.

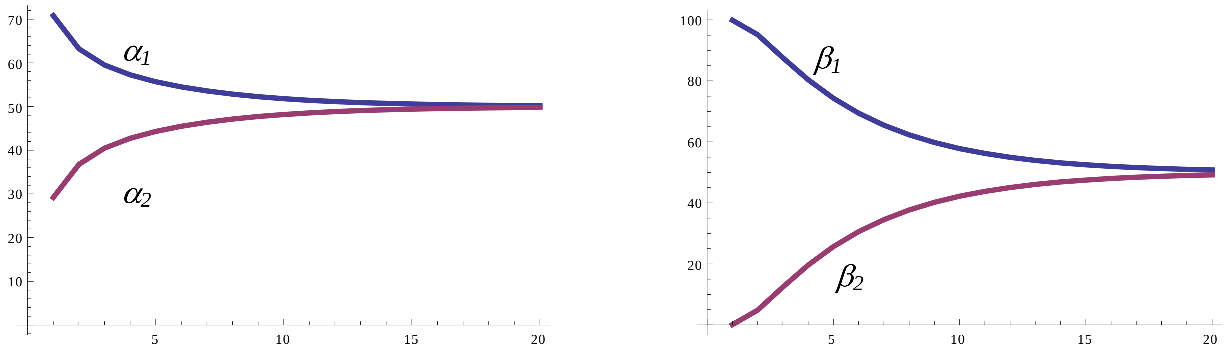

Figure 6: Market Shares in Consumer and Content Provider Markets
(Default inputs with $n_1 = n_2 = 0$)

When externality factors are negligible, competition becomes more intense, since the initial incumbent advantage due to large market share is reduced. If, in addition, platforms are not able to charge fixed subscription fees to content providers, entry remains possible in the customer market, but not in the content provider market as illustrated in Figure 7.[7]

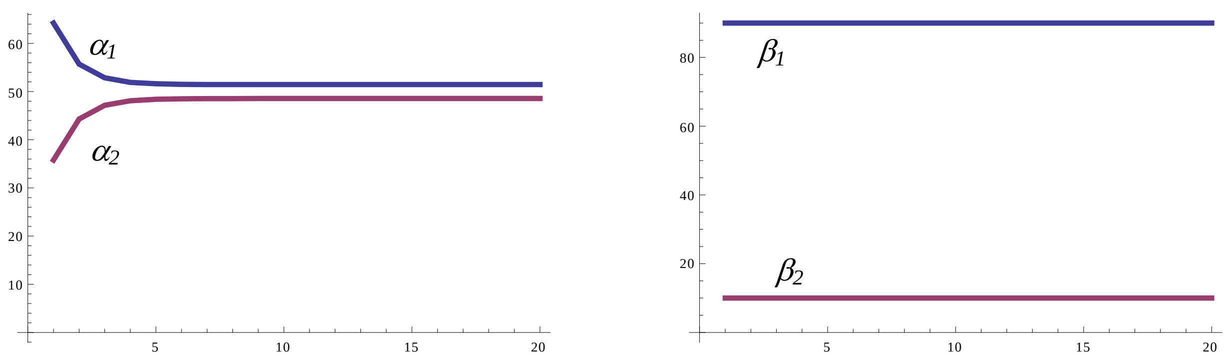

Figure 7: Market Shares in Consumer and Content Provider Markets
(Default inputs with $n_1 = n_2 = 0$ and zero externalities)

3.2.3 Price Discrimination

When platforms are allowed to discriminate between on-net and off-net services, price competition becomes more intense in our framework, with the result that entrants face increased barriers to entry. Computational results are sensitive both to the assumed starting values for initial market shares (α_1 and β_1) and the competition intensity factors (Z_C and Z_P). Consumer voice and data prices follow price paths that are consistent with Proposition 2. On-net prices for both voice and data as well as off-net prices for voice are identical after a few initial periods. Platform 1 subsidizes data traffic for its subscribers who request content from a provider on platform 2, since in doing so it can compete for these customers while avoiding the marginal cost of originating data traffic. Platform 2 charges an off-net price for data traffic that is greater than

[7] Proposition 7 below demonstrates generally that entry or exit in the content provider market never occurs when content provider externality factors P_{X1} and P_{X2} are equal to zero and there are no subscription fees for content providers.

the marginal cost of termination.[8] Figure 8 illustrates these results when competition intensity factors are Z_C, = 12,000 and Z_P = 5,000.[9]

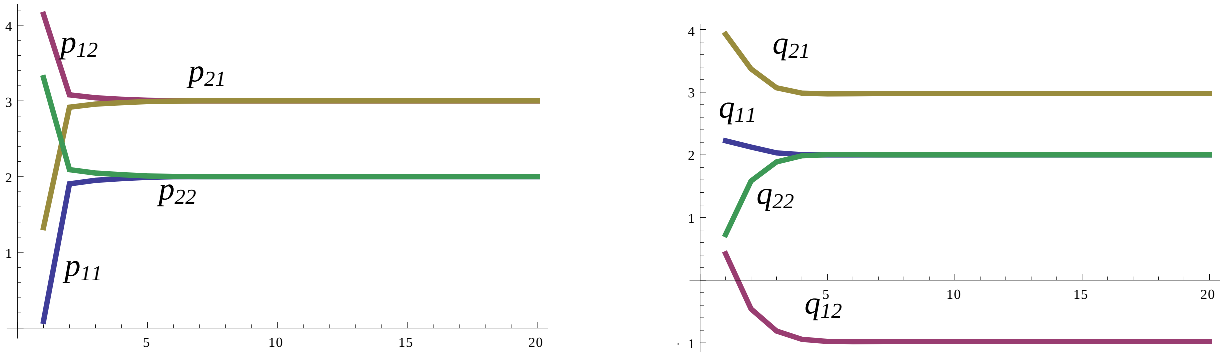

Figure 8: Consumer Voice and Data Prices
(Price Discrimination with Z_C = 12,000, Z_P = 5,000 and initial market shares = 0.6)

Consumer market shares are approximately equal to 50% for each platform in all periods, while platform 1 increases its initial content provider market share from an initial 60% to 75% after 20 periods. Platform 1 is also able to earn consistently higher profits than platform 2 under price discrimination.

3.2.4 Evaluation of Duopoly Performance

The above results suggest that in a wide variety of circumstances, duopoly competition ultimately results in entry by the smaller competitor up to the point at which market shares in both consumer and content provider markets are equal. To the extent that entry barriers exist, they depend, in the present model, on factors that are beyond of the ability of regulators to control. These include the degree of customer loyalty to an existing platform and the observable magnitude of network externalities. The rate structure used by next generation platforms in setting prices for content providers, and the ability of platforms to price discriminate between on-net and off-net users are important institutional features, which can, to some extent, determine the outcomes of competitive market competition.

Table 3 shows summary results for surplus and profit for five different competitive simulations, using the default input assumptions (except where indicated). Total surplus is relatively constant in each of the scenarios. An increase in the competition factors reduces consumer surplus, while increasing platform profit. When subscription fees to content providers are not possible, provider profit increases dramatically at the expense of platform profit. Price discrimination has only a minor effect on the distribution of surplus.

[8] In the default input assumptions, there are no terminating access charges for data traffic.
[9] Similar results are obtained when initial market shares of firm 1 are equal to 90%. In this case, however, we have obtained stable equilibrium computations using market intensity factors $Z_C = Z_P$ = 50,000.

Table 3: Surplus and Profit under Different Competitive Scenarios
(Default inputs unless otherwise specified)

	Total Surplus	Consumer Surplus	Provider Profit	Platform Profit
Competition Default inputs	13112	2859	3584	6669
Competition ZC = 12000, ZP = 5000	13108	15	2320	10772
Competition n1 = n2 =0	13039	2873	7121	3045
Competition ZC = 12000, ZP = 5000 n1 = n2 =0	13019	35	7118	5867
Competition with Price Discrimination ZC = 12000, ZP = 5000 $\alpha 1(0) = \beta 1(0) = 0.6$	13013	2	2994	10017

3.3 Network Neutrality

The Internet was designed as an open network with "no gatekeepers over new content or services" (Cerf, 2006). Its layered, end-to-end architecture places network intelligence at the edges rather than at the core. Such technical features are usually highlighted as the sources of the wide range of services and innovative offerings seen on the Internet ever since it turned into a commercial enterprise. In recent years, several cases, regarded mainly as potential threats to the introduction of innovative services, have been in the spotlight as they have either been deemed anticompetitive or raised attention due to their controversial nature. In 2004, Madison River Communications obstructed the use of VoIP service from Vonage to Madison's DSL customers (FCC, 2005). In 2007, Comcast was accused of blocking peer to peer traffic on its networks. According to the company, this practice was part of its network administrative decisions to relieve congestion (FCC, 2008). Clement and Longford (2007) allege that Canadian telephone operator Shaw intentionally worked to "reduce the quality" of VoIP services to its competitors, forcing their customers to buy an additional service provided by Shaw as a strategy to make its rivals look as though they were providing a lower quality of service. In Chile, Telefónica CTC acknowledged that it blocked access to the ISPs' operating VoIP on its platform MegaVía. RedVoiss, one of the affected ISPs, filed a complaint against Telefónica for anticompetitive behavior (Alvear, 2008).

These cases are useful in profiling the network neutrality debate. The network neutrality principle requires any operator to not discriminate against content that travels on its network, or against particular websites and devices used to access the Internet. Discrimination can be defined as the unequal treatment of applications and content from whoever manages or handles the network, seeking individual benefit, without the consent or all market participants (Marsden and Cave, 2007).

Some network neutrality advocates argue that network operators should not distinguish in terms of price between packets belonging to different services; neither should they price-discriminate between the up-loader and the down-loader of information. As some of the above cases suggest, large telecommunication operators with considerable market power defend discriminatory practices according to the type of application and the provider used to transmit the content. Such operators would like to have in place a more complex pricing scheme that would allow them to impose price discrimination on the provider's side of the market, charging fees to a traffic originator even when the originating party does not connect to the Internet by using their networks and, therefore, does not have any contractual relationship with them (Yoo, 2006). This is what the so-called "two-sided pricing" practice implies – imposing price discrimination on the provider's side of the market and not on the subscriber's. In this section, we use the NGN competitive model as described above in order to evaluate some of these claims.

In this section, we focus on the role that platform competition plays in determining equilibrium levels of content provision in a next generation network.

3.3.1 Discrimination in NGN

ISPs' commonly accepted practices are such that they reflect the network neutrality principle; that is, ISPs charge consumers only for access, don't have a preference for one content provider to another, and don't charge content providers for sending contents to end users (Hah and Wallsten, 2006). As networks consolidate through vertical integration, their ability to become discriminatory platforms increases. Platforms therefore have the incentives to charge content providers either usage fees, by means of per minute charges, or to offer preferential agreements to particular content providers.

Advances in new technologies may provide the grounds for platforms to exert different types of behavior that would violate network neutrality principles. Such behaviors are typically discriminatory in nature and may be classified as (Kocsis and de Bijl, 2006) port blocking, quality degradation, and access-tiering. The Madison River case exemplifies a case of port blocking in which voice over internet protocol (VoIP) services were deliberately blocked on its network. Technology can also provide an operator with the ability to degrade the quality of transmission from content providers that deliver applications or contents. On the other hand, a platform can also give bandwidth priority to preferred content providers to application and service providers as long as providers are willing to pay premiums on top of internet access fees; such practices can potentially create content provider tiers that discriminate them on the basis of their willingness to pay.

The use of "IP" as the supporting network layer protocol confers on NGN platforms the ability to discriminate among traffic flows. The header of an IP packet contains information that can be used to deliberately act upon packets that originate at a certain content provider website or are intended to be carried to a specific destination. As asserted in (Peha, 2007), learning about a packet stream from a single packet is quite difficult, but technological advances in packet flow recognition are currently providing platform with practical forms of traffic recognition and discrimination. At the IP level, platforms could use flow classification or deep packet inspection, and finer-grain discrimination by means of appropriately using the packet scheduling and dropping algorithms at the traffic control layer (Peha, 2007).

3.3.2 Usage Fees for Content Providers

In this section we use our model to investigate the extent to which relevant values of surplus and profits change as a platform decides to charge content providers for their traffic into the network through usage fees; this is clearly an exemplification of a discriminatory activity exerted by a platform in violation of network neutrality principles.

First, consider the case in which platform operators are able to charge per minute usage fees to content providers. As explained in Beltrán and Sharkey (2008), stable competition is possible only if these usage fees are set by contractual arrangement, rather than non-cooperatively, using the full set of first order conditions (9). As the content supply function, equation (3) demonstrates, a provider's willingness to invest in content is inversely related to the level of usage fees that platforms charge. Table 4 documents how providers respond to these charges, and how these decisions have an impact on the relevant values of surplus and profit.[10]

Table 4: Competitive Surplus and Profit
(Default inputs)

Negotiated Provider Prices $r_{11} = r_{12} = r_{21} = r_{22}$	Total Surplus	Consumer Surplus	Provider Profit	Platform Profit	Final Period Content
3.00	10870	2898	3514	4458	0.8
2.00	12341	4623	3899	3820	1.75
1.00	13066	4274	3848	4944	2.40
0.00	13112	2859	3584	6669	2.75
-1.00	12601	1164	3274	8163	2.80
-2.00	11715	-242	3028	8929	2.55
-3.00	10690	-1012	2901	8801	2.00

Table 4 demonstrates that content provider profits do not significantly change as usage fees for content are varied. Platform profit is generally higher and consumer surplus is generally lower when usage fees for content are reduced. Platforms are able to capture a significant portion of the consumer surplus in the consumer data market through higher consumer user charges (equation 12), higher consumer subscription fees and higher subscription fees for content providers. At some point, however, subsidies to content providers and higher usage charges that platforms impose on consumers reduce the profit potential from advertising revenues for the content provider.

We next consider in more detail the role of content usage fees on general welfare computations. Total surplus is maximized under the default input assumptions when usage fees for content are positive, and

[10] Recall from section 2 that each unit of *Content* represents a horizontal shift in consumer demand for data services.

approximately equal to 0.4 (assuming subscription fees are also possible). Optimal values of content usage prices, under both competition and regulation, depend on the profit potential in the content market. As described in section 2, content providers earn revenues from advertising, which in our model depends directly on the number of units of data traffic, x_{Data}, that consumers are willing to purchase, and indirectly on the value of each minute as determined by the input parameters *AdRevMultiplier* and *ProviderVariableCost*. When consumer data usage prices are determined optimally, surplus maximization requires that content provision should be subsidized to some extent based on the profitability of the content provision market.

Under regulated monopoly or duopoly, the size of this subsidy decreases as the profitability of the content provision market increases. Under duopoly competition (with zero content provider usage fees), equilibrium prices for consumer data services are greater than their surplus maximizing values. It is therefore desirable for platforms to impose positive usage charges on content providers as long as the content market is sufficiently profitable, so that retail consumer prices are reduced as predicted by Proposition 1. The size of this tax on content increases as content provision becomes more profitable (through higher advertising revenues or lower costs), since it becomes increasingly efficient to give platforms an incentive to lower consumer data prices by increasing platform revenues through usage fees from content providers. This result follows because end user consumers ultimately determine the volume of data traffic on a next generation network.

Table 5 documents these results by showing the values of content usage fees (assuming subscription charges are also possible) that maximize total surplus under two different regulatory situations: regulated duopoly and full duopoly competition. These results are based on differing values of advertising revenues, but similar results are obtained when marginal costs of providing content vary.

Table 5: Total Surplus (TS^* or TS^{eq}) when Data Outputs (q^* or q^{eq}) and Content Usage Fees (r^*) are Jointly Optimized

(Default inputs unless otherwise stated)

AdRevMultiplier	Regulated Duopoly			Competitive Duopoly		
	q*	r*	TS*	q^{eq}	r*	TS^{eq}
.5	2.67	-1.33	10854	3.37	-.37	10711
0.75	2.29	-1.14	11989	2.94	.06	11754
1	2	-1	13498	2.58	.42	13169
1.5	1.6	-0.8	17665	2.05	.95	17160
2	1.33	-0.67	23397	1.69	1.31	22740

In this section we have considered the impact of two different regulatory instruments that have an impact on consumer data prices under duopoly competition as content provision, (defined by the input variable *AdRevMultiplier*), varies. In Table 5, we describe the results of setting content usage charges optimally when termination charges for data service are set equal to zero according to the default input assumptions. A comparison of these results suggests that setting termination charges optimally results in somewhat higher levels of total surplus than using only content provider usage fees as an instrument. As Table 5 also demonstrates, a first best solution requires setting both consumer data usage charges correctly to generate optimal call volume, and setting content provider charges to generate optimal levels of content. While Proposition 1 shows that both termination charges and content usage fees have an impact on competitive platforms' choice of consumer data prices, the dual goals for a first best solution cannot be achieved by setting either termination charges or content usage charges alone. In fact, the two goals are in conflict when only content usage charges are available as a tool, since low customer data prices require higher content usage fees, while optimal content provision requires lower fees. It is, however, possible to achieve the first best solution by optimally selecting both termination charges and content usage fees in accordance with equation (12) from Proposition 1.

3.3.3 Blocking of Off-Platform Content

Platforms have the ability to block traffic originated at specific sources or block all potential incoming traffic originated off its network. Therefore, in this section we assume that provider content is only available to customers on the same platform as the provider's chosen platform. Consequently, we modify the "balanced traffic" assumption to reflect the fact that each consumer's data traffic is now directed only to on-platform content providers. Under the default input assumptions, market dynamics are broadly consistent with outcomes predicted without content blocking (Figures 1 through 4). When subscription charges are *not* imposed on content providers, results are also similar to results without content blocking (Figures 8 and 9), although market shares and operator profits converge significantly more slowly.

While blocking of off-platform content does not significantly change the prospects for entry or exit, it does have an impact on total surplus, and the distribution of surplus in the competitive outcomes. Table 6 shows the summary measures of surplus and profit using the default input values. A comparison with Table 3 shows that when subscription fees for content are feasible, total surplus, consumer surplus and platform profit are lower under content blocking, while content provider profit is higher. When provider subscription fees are not possible, total surplus, consumer surplus and provider profit are lower, while platform profit is higher.

Table 6: Surplus and Profit with Blocking of Off-Platform Content

	Total Surplus	Consumer Surplus	Provider Profit	Platform Profit	Final Period Content_1	Final Period Content_2
Default Inputs	11911	1306	4987	5617	1.42	1.42
Default Inputs $n_1 = n_2 = 0$	11546	1393	6522	3630	1.20	1.20

4 Concluding Comments

In this paper we have presented results of a computational tool for the analysis of competition in the telecommunications industry as that industry evolves from one centered on voice communications services to one in which consumers, independent firms offering information services and network operators all interact using next-generation networks as their fundamental infrastructure.

Section 3.1 presented a base case model which roughly corresponds to the set of current pricing arrangements for both voice and data services. In the base case, consumers pay both a fixed subscription fee and a usage based fee, while content providers pay only a fixed charge for the right to transmit data messages to consumers. Section 3.2 examined ways in which model input parameters determine the rate and direction of competitive entry or exit. While these factors are largely not subject to regulatory control, they are important for regulators to understand in framing a coherent regulatory (or de-regulatory) policy. Section 3.3 provides results that are potentially relevant to the important debate on network neutrality – specifically, the consequences of usage prices charged to content providers and the ability of platforms to block off-platform content. These results show that usage fees to content providers can to some extent be used to correct distortions in the setting of retail data prices for end user consumers. In addition, content blocking is shown to be potentially harmful to the interests of consumers though not for content providers. While keeping in mind that the reported results are relevant only to the specific model presented, it is hoped that the results of this analysis can be of use in guiding future policy decisions.

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Appendix: Default Inputs

The following set of parameter values are used unless otherwise stated in the text of the paper.

Competitive Intensity	**Customer Demand**	**Marginal Costs**
Z_C = 7500	*aVoice* = 10	$c_{11} = c_{21} = 1$
Z_P = 3000	*bVoice* = 0.02	$c_{12} = c_{22} = 1$
Network Externality	*aData* = 8	$d_{11} = d_{21} = 2$
ConsumerFixedUtility = 5000	*bData* = 0.02	$d_{12} = d_{22} = 2$
ProviderFixedUtility = 5000	**Content Provider Supply**	**Fixed Charges**
$C_{X1} = 0.3$ $C_{X2} = 0.2$	*ProviderVC* = 500	$f_{C1} = f_{C2} = 2000$
$P_{X1} = 0.2$ $P_{X2} = 0.1$	*ProviderFC* = 1000	$f_P = 0$
Initial Market Shares	*AdRevMultiplier* = 1	**Access Charges**
$\alpha_1(0) = 0.9$	**Discount Rate per Period**	$ta_{1Voice} = ta_{2Voice} = 2$
$\beta_1(0) = 0.9$	$\delta = 0.976$	$ta_{1Data} = ta_{2Data} = 0$

In addition, our default input assumptions assume that subscription fees for content providers are feasible, and that usage fees for content providers are not feasible (therefore assumed to be equal to zero). In addition, content provided on either platform is assumed to be made freely available to subscribers on both platforms. All other input parameters consist of technical parameters such as starting values and scaling factors. These are available from the authors upon request.