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THE VERTICAL INTEGRATION OF CONTENT AND BROADBAND SERVICES: THE NET NEUTRALITY DEBATE

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Abstract

Whether broadband service providers should be allowed to vertically integrate with content providers is a contentious issue, especially from the net neutrality perspective, since the vertically integrated firm can prioritize the delivery of its own content at the expense of that of its competitors if net neutrality is not enforced. We analyze the issues of vertical integration of content and broadband services surrounding this debate from an economic perspective, using a game-theoretic model. Our analysis establishes the various equilibria in the game, and shows that if net neutrality is not enforced, social welfare might – depending on parameter values – increase or decrease with vertical integration. Interestingly, we find that it is not always true that the ISP will always degrade the delivery of the competing content, and in fact will sometimes have the incentive to prioritize the latter over its own.

Keywords: *Net Neutrality, Economics of Net Neutrality, Vertical Integration, Broadband Service Providers, Content Providers, Social Welfare*.

1 INTRODUCTION

The issue of net neutrality received widespread media attention when some broadband providers like Verizon, Comcast and AT&T (among others) proposed to charge popular online websites for priority delivery of the latter's content to their residential and commercial customers (Helm 2006, Waldmeir 2006). The proposal encountered stiff resistance from those who were supposed to be charged, and thus erstwhile competitors like Google, Yahoo! and Microsoft were soon lobbying before the United States Congress to pass legislation that would prevent the Internet service providers (ISPs) from carrying out their proposed plan (WSJ 2006), and thereby maintain what was termed the 'neutrality' of the Internet (the term 'net neutrality' itself is attributed to the Columbia Law School professor Tim Wu). This would involve the designing of "rules that prevent network operators and ISPs from using their power over the transmission technology to negatively affect competition in complementary markets for applications, content and portals" (van Schewick 2007).

The supporters of net neutrality believe that a "maximally useful public information network aspires to treat all content, sites, and platforms equally" (Wu 2003), and while a formal definition of the operationalization of the principle does not exist, Hahn and Wallsten (2006) point out that it "usually means that broadband service providers charge consumers only once for Internet access, do not favor one content provider over another, and do not charge content providers for sending information over broadband lines to end users."

As is to be expected in a debate which has implications in many different areas, academicians too can be found on both sides of the debate (for a recent example of such debate, see (van Schewick and Farber 2009), for example). The issues that are germane to the research in this paper are economic in nature. As Economides and Tag (2007) point out, in sharp contrast to the large amount of literature that discusses the legal issues surrounding net neutrality, there is a surprising lack of rigorous economic analysis of the net neutrality debate. For a comprehensive analysis, we need to consider the strategic interactions between the three players involved in this issue: the content providers, who jockey for a position in the consumers' minds; the consumers, who gain utility by consuming the content of the content providers but endure the disutility of congestion by waiting for this content; and the Internet service provider, who charges the consumers for access to the content, and, depending on the legislation on this issue, can decide to charge the content providers for preferential treatment of the latter's content – all within a two-sided market framework.

Cheng, et al. (2009) consider the effect of competition among content providers by limiting the number of content providers to two, who do not effectively differ in quality, but are differentiated from each other in terms of consumers' content preferences in a Hotelling sense. They find that net neutrality can sometimes result in lower social welfare in the short run, but when capacity expansion is an endogenous choice (i.e. in the long run) in the model, the ISPs have a higher incentive to expand under net neutrality in most scenarios, thus undermining one of the key arguments of the opponents of net neutrality – that ISPs will not have sufficient incentive to expand capacity under net neutrality.

The literature on net neutrality thus far – especially those which look at the issue from an economic perspective – look at the problem assuming that the ISP and the content providers are separate entities with conflicting objectives, with the two standing on opposing sides in this debate. However, recent developments indicate that the issue might not be that clearly delineated: broadband service providers like Comcast and AT&T have struck deals with online content providers whereby the latter provides exclusive co-branded content through the former's 'pipes'. For example, Comcast and Yahoo! recently signed a multi-year agreement so that the latter can display its advertisements to the end consumers who subscribe to the former's broadband services (Shields 2007). As industry observers have noted, abolishing net neutrality might provide the incentive to the ISP to generate their own content (or equivalently, have a strategic relationship with a content provider) and then prioritize delivery of such content to the end consumers. If net neutrality is not enforced, and the ISP's in these examples are allowed to prioritize content from their strategic partner, a section of the consumers might switch from their erstwhile content provider to the ISP's strategic partner. A similar scenario can ensue with other classes of service like news, VoIP telephony, music streaming, etc.

These developments prompt a new set of questions for the policymaker:

1. What are the possible different equilibrium outcomes when ISP is vertically integrated with a content provider?
2. How does such vertical integration affect consumer surplus and social welfare?
3. Will the vertically integrated firm prefer no net neutrality over net neutrality?

In this paper, we endogenize the ISP's vertical integration decision in the context of the net neutrality debate to answer these questions. In our model, we assume that there is a monopolist ISP who gets into a strategic relationship with an online content provider to provide an online service that competes with that from a pure play competitor. The latter has to depend on the ISP's infrastructure for getting its content delivered to the end consumers. We assume that the content providers get reimbursed through an advertisement-supported revenue model that allows them to provide their service to the end consumers for free (this revenue model is further expanded upon in the next section).

Our analysis shows that depending on the effectiveness of the vertically integrated ISP in generating revenue as compared to its competitor, consumer surplus and social welfare may increase or decrease as compared to the equivalent scenarios when the ISP is not vertically integrated. Further, our analysis also indicates that given the choice, the vertically integrated ISP does not ever have the incentive to abide by the principles of net neutrality. Consumers sometimes gain from arrangements with lower access charges, while the rival pure play content provider is never better off. We find that interestingly it is not always true that the ISP will always degrade the delivery of the competing content, and in fact might sometimes prioritize the content of its competitor over its own.

The rest of the paper is arranged as follows. Section 2 develops the theoretical model on which our analysis is based. Section 3 analyzes the three players' decisions under net neutrality (which we denote as NN for short) and Section 4 analyzes their decisions with no net neutrality (or NNN for short). Section 5 examines the welfare impact of net neutrality in the context of vertical integration. Section 6 concludes with a discussion of our findings and their implications.

2 THE MODEL

In this section we set up a game-theoretic model to analyze the impact of vertical integration between content provider and broadband service provider in the absence of net neutrality. There are three types of players in the game – the vertically integrated monopolist ISP, the two content providers (one of whom shares a strategic relationship with the ISP) and the end consumers. The ISP serves as an intermediary and transmits content from the content providers to end consumers. Since the ISP is vertically integrated, it has its own content (from its strategic partner) that competes with the other independent content provider (we call the independent content provider C) for the attention of the end consumers.

As stated earlier, we assume a monopolist ISP delivering the digital content from its local switching office to the end consumers. While the monopoly assumption is a simplification in some geographies, it is to be noted that unlike many other countries, the extent of competition in the local broadband services market is very limited in the United States, so much so that in many places, a single broadband service provider is often a de facto monopolist (Economides 2008, Hausman, et al. 2001). Some of the factors leading to this scenario are the high switching costs induced by long-term service contracts and by incompatible broadband technologies between cable and phone companies. Further, many customers are not qualified for digital subscriber's line (DSL) broadband services from phone companies because they exceed the three miles distance limit from the phone company's nearest switching office, making the cable operators the only feasible broadband service providers in several local markets (Turner 2007). Thus, in addition to providing the benefit of making the analysis tractable, the assumption closely reflects the reality of local broadband services in the U.S. market. As is common in the online world nowadays, we assume that the content providers provide their content to the consumers for "free" and get compensated indirectly in a stochastic sense from "a revenue-generating component somewhere in the value chain" (McKinseyQuarterly 2009). This revenue model follows what many researchers, from economists like Hal Varian (McKinseyQuarterly 2009) and Paul Krugman (2008), to IS researchers like Eric Clemons (Knowledge@Wharton 2008) think is the way digital content would be paid for as their marginal cost is driven towards zero.

2.1 Broadband Service Provider

Following the central tenets of the model in (Cheng, et al. 2009), we assume a monopolist ISP who provides Internet access as well as its own content to the end consumers. The ISP can provide its content as a result of a vertical integration with a content provider – the exact mechanism for this integration might be achieved through an outright merger between the two firms, or through a strategic alliance.1 The mechanism of this integration is discussed later in the text. Figure 1 shows a schematic of the market structure of the model.

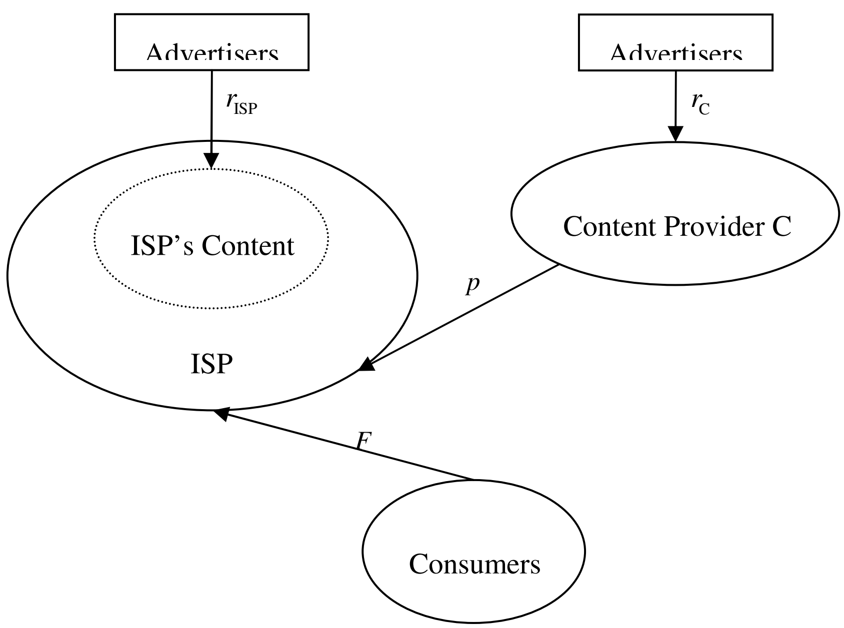

Figure 1. Market structure

The ISP charges the consumers a fixed fee F for Internet access and potentially charges content provider C a usage-based fee p for preferential delivery of C's data packets if net neutrality is not enforced. In this

[1] The details of the profit-sharing agreement between the two firms in a strategic alliance are not germane to this discussion, since what we are concerned about is the effect on social surplus.

context, we note that the technology to discriminate packets and streamline Internet traffic has been available at minimal fixed cost, and we therefore assume that there is no additional expense incurred by the ISP to implement a mechanism that enables preferential delivery of content (Cheng, et al. 2009). The ISP's capacity is denoted by μ.

2.2 Content Provider

To model the competition between the content providers, we assume two content providers L and H who offer their basic services for free to the end consumers. We assume that the content from these two providers are horizontally differentiated in a Hotelling sense with the two of them located on the two ends of line segment $[0,1]$. The content providers get compensated when the consumers interact with advertisers and other revenue generation mechanisms on the content providers' web sites. Examples of such revenue generation mechanisms include banner advertisements, affiliate revenues, rental of subscription lists, sale of aggregate information, licensing, live events, listing, paid inclusion, cost per install, getting users to create content for free, streaming audio and video advertising, and API fees, to name a few (Wilson 2008). We capture this revenue model of the two content providers through two separate variables which represent the average revenue generated (from all sources) per packet requested by the end consumer, r_{H} and r_{L}, where, without loss of generality $r_{\mathrm{H}} > r_{\mathrm{L}}$. These two variables denote the revenue rates of the two content providers respectively per packet for content – in other words, these two parameters denote the average rates at which the requests for content from the consumers provide revenues to the content providers from myriad third parties who want to reach these consumers. As is observed in real life, content providers differ in their ability to get the "right" consumers for their respective advertisers (and other revenue sources) and therefore end up charging different advertising (and other) fees.

The ISP has two decisions to make: (a) whether it would like to have a strategic relationship with one of the two content providers and (b) if so, which one. We denote the revenue generation rate of the vertically integrated ISP by r_{ISP} and the revenue generation rate of the independent content provider C, where $\mathrm{C} \in \{\mathrm{H}, \mathrm{L}\}$, as r_{C}. Thus, $r_{\mathrm{ISP}} = r_{\mathrm{H}}$ and $r_{\mathrm{C}} = r_{\mathrm{L}}$ if the ISP vertically integrates with H, and $r_{\mathrm{ISP}} = r_{\mathrm{L}}$ and $r_{\mathrm{C}} = r_{\mathrm{H}}$ if the ISP vertically integrates with L. Therefore, depending on the ISP's choice, r_{ISP} can be either greater than or less than r_{C}. The competition between content provider C and the ISP is driven by the fact that a larger consumer base will lead to greater advertising revenue.

2.3 Consumers

Consumers request content from either the ISP or content provider C. We model the congestion in the network after (Bandyopadhyay and Cheng 2006, Mendelson 1985), and accordingly, consumers' request for data packets follows a Poisson process with arrival rate λ. The gross valuation consumers receive is denoted by $V(\lambda)$. Consumers face a delay cost due to network congestion during the data transmission process. We note that the issue of net neutrality ceases to be one if consumers do not experience any delay: if the ISP cannot credibly speed up content in lieu of a fee, then the problem would not exist. As noted in the afore-mentioned literature, we assume an M/M/1 queue to model the data transmission service provided by the ISP. Then the time spent in the system by a data packet is $\frac{1}{\mu - \lambda}$ (with net neutrality enforced, i.e. when no packet has priority over another) and the corresponding delay cost is

$\frac{d}{\mu-\lambda}$ where d is the delay parameter that captures the unit cost of delay for consumers waiting for the content to arrive from the content providers. As discussed earlier, the consumers are uniformly distributed on $[0,1]$ in terms of their preferences for content (as shown in Figure 2), with an associated fit cost. For an arbitrary consumer $\tilde{x}\in[0,1]$, the fit cost associated with deviation from his ideal content is $t\tilde{x}$ if the consumer chooses the ISP's content and $t(1-\tilde{x})$ if the consumer chooses content from provider C. Then the utility function for the ISP's consumers under net neutrality is:

$$u_{\text{NN\_ISP}}(\tilde{x})=V(\lambda)-t\tilde{x}-\frac{d}{\mu-\lambda}-F \qquad (1)$$

The utility function for content provider C's consumers under net neutrality is:

$$u_{\text{NN\_C}}(\tilde{x})=V(\lambda)-t(1-\tilde{x})-\frac{d}{\mu-\lambda}-F \qquad (2)$$

We define two indicator functions as follows to represent whether the ISP would prioritize its own content and whether content provider C would pay for the preferential delivery.

Figure 2. Content competition between the ISP and content provider C

$$I_{\text{ISP}}=\begin{cases}1, & \text{The ISP prioritizes its own content}\\ 0, & \text{The ISP does not prioritize its own content}\end{cases} \qquad (3)$$

$$I_{\text{C}}=\begin{cases}1, & \text{Content provider C pays for the preferential delivery}\\ 0, & \text{Content provider C does not pay for the preferential delivery}\end{cases} \qquad (4)$$

The timing of the four-stage game is as shown in Figure 3.

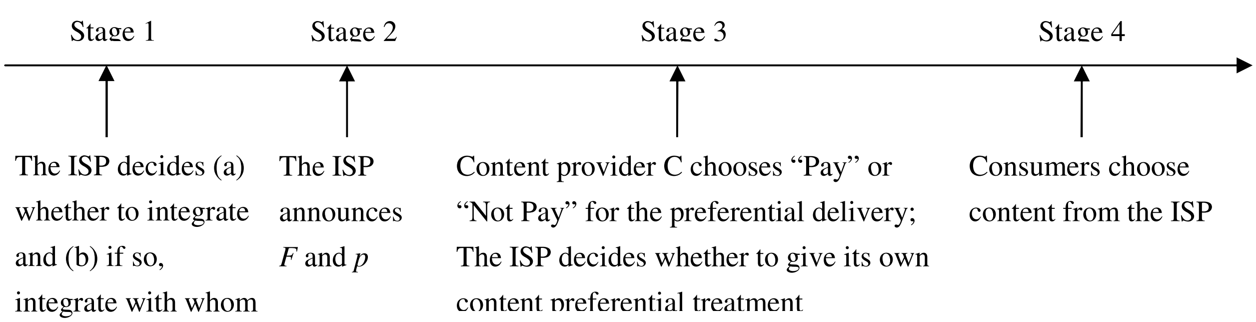

Figure 3. The four-stage game

In stage 1, the ISP decides (a) whether to integrate and (b) if so, integrate with whom. In stage 2, the broadband provider announces F and p. In stage 3, content provider C chooses to "Pay" or "Not Pay" for the preferential delivery and the ISP decides whether to give its own content preferential treatment. In stage 4, consumers choose content from either the ISP or content provider C. Given this particular timing, the strategy of the ISP is to calculate its optimum profit under different scenarios, and then, depending on the underlying parameter values (see Appendix A for a list of the various parameters and variables used in the text), choose whether to observe net neutrality, or – if the regulatory environment allows him to do so – choose to prioritize its own content and (for a fee) the content from provider C to the end consumers. Thus, the monopolist ISP can calculate what would be the profit under different scenarios and then choose that particular pricing strategy that will maximize its profit for a given set of parameter values. In the following sections 3 and 4, we analyze these different scenarios by maximizing the ISP's profit objective under different regulatory regimes (net neutrality and no net neutrality) and pricing arrangements. Note that there is only one pricing decision under net neutrality (the access price that the ISP charges the consumers), while under no net neutrality, the ISP can charge both the consumers and the content provider C (charging the latter for the service that prioritizes the delivery of its content to the end consumers).

3 NET NEUTRALITY

With net neutrality in place, the ISP is forbidden from providing the service of and charging for preferential delivery of data packets. Then the marginal consumer who is indifferent from the ISP and content provider C can be determined by $u_{\text{NN\_ISP}}\left(x_{\text{NN}}\right) = u_{\text{NN\_C}}\left(x_{\text{NN}}\right)$, i.e.,

$$V(\lambda) - tx_{\text{NN}} - F_{\text{NN}} - \frac{d}{\mu - \lambda} = V(\lambda) - t(1 - x_{\text{NN}}) - F_{\text{NN}} - \frac{d}{\mu - \lambda} \quad (5)$$

which implies $x_{\text{NN}} = \frac{1}{2}$.[2] Therefore the demand for the ISP and content provider C are both $\frac{1}{2}$. The resulting Internet access fee is $F_{\text{NN}} = V(\lambda) - \frac{t}{2} - \frac{d}{\mu - \lambda}$. The ISP's revenue consists of both Internet access charge from consumers ($V(\lambda) - \frac{t}{2} - \frac{d}{\mu - \lambda}$) and advertisement revenues from advertisers ($\frac{1}{2}\lambda r_{\text{ISP}}$).

4 NO NET NEUTRALITY

Without net neutrality, the ISP has the option to provide a preferential delivery for data packets from content provider C and the ISP itself. Depending on whether the ISP prioritizes its own content and whether C pays for the preferential delivery, there are four different outcomes: (1) C does not pay for priority delivery of its own content, and content from neither provider is prioritized (Outcome 1); (2) the ISP prioritizes its own content at the expense of that of C who does not pay the priority delivery fee (Outcome 2); (3) the ISP prioritizes C's content for a fee so that the latter's content is prioritized at the expense of its own (Outcome 3); and (4) C pays the ISP so that the ISP does not prioritize its own content over that of C (in other words, content from both providers receive the same priority) (Outcome 4). Note that all these four outcomes are under the "control" of the ISP – for example, if it is charging C for priority delivery, it can create a contract that specifies whether it will in turn not prioritize its own content (i.e. Outcome 3), or whether the payment from C merely ensures that C's packets are not relatively "de-prioritized" with respect to its own (which is Outcome 4). We note further that *a priori*, none of the

[2] The subscripts for the parameter x denoting the indifferent consumer signify the different "regimes" under which the analysis is done. Thus, the subscript NN denotes net neutrality, while the subscripts 1 through 4 that appear later in the text signify the four different scenarios under no net neutrality.

outcomes can be ruled out, since based on the values of the different parameters, any one of them might generate the highest profit for the ISP.

Outcome 1: The ISP does not prioritize its own content and content provider C does not pay for the preferential delivery ($I_{\text{ISP}} = I_{\text{C}} = 0$).

Outcome 1 is essentially the equilibrium under net neutrality. The corresponding marginal consumer x_1 is determined by $u_{\text{ISP1}}(x_1) = u_{\text{C1}}(x_1)$, i.e.,

$$V(\lambda) - tx_1 - F_1 - \frac{d}{\mu - \lambda} = V(\lambda) - t(1 - x_1) - F_1 - \frac{d}{\mu - \lambda} \tag{6}$$

which implies $x_1 = \frac{1}{2}$. Under this scenario, the ISP's problem is:

$$\begin{aligned} &\max_{F_1, p_1} \ \pi_{\text{ISP1}} = F_1 + \frac{1}{2}\lambda r_{\text{ISP}} \\ &\text{s.t.} \quad u_{\text{ISP1}}(\tilde{x}) \ge 0, \quad 0 \le \tilde{x} \le x_1 \\ &\qquad u_{\text{C1}}(\tilde{x}) \ge 0, \quad x_1 \le \tilde{x} \le 1 \\ &\qquad \pi_{\text{ISP1}} - \pi_{\text{ISP2}} \ge 0 \\ &\qquad \pi_{\text{C1}} - \pi_{\text{C3}} \ge 0 \end{aligned} \tag{7}$$

where the first two constraints are consumers' participation constraints and the last two are incentive compatibility constraints for the ISP and content provider C. Note that for its incentive compatibility considerations, the ISP compares its profit under Outcome 1 with that under Outcome 2 (where it prioritizes its own content over that of C). To consider the incentive compatibility constraint of content provider C, meanwhile, the ISP will need to compare C's profit under Outcome 1 to that under Outcome 3 – when it prioritizes C's content at the expense of its own.

Some algebra shows that regardless of parameter values, the incentive compatibility constraint for the ISP can never be satisfied. In other words, if content provider C does not have the incentive to pay for the preferential delivery, the ISP is always better off to prioritize its own content (see Table 1 for a comparison of the ISP's profits under the different scenarios). Therefore Outcome 1 is not an equilibrium, unless the ISP is prohibited through regulation from differentially prioritizing content.

Outcome 2: Under Outcome 2, the ISP finds it optimal to prioritize its own content and content provider C does not have the incentive to pay for the preferential delivery ($I_{\text{ISP}} = 1, I_{\text{C}} = 0$).

In this case, data packets provided by the ISP and content provider C are transmitted with different priorities by the ISP. We use a two-class priority queue with preemption model to depict the waiting time. Data packets from the ISP are transmitted with higher priority whose waiting time is $\frac{1}{\mu - x_2\lambda}$ while data packets from content provider C are transmitted with lower priority whose waiting time is $\frac{\mu}{(\mu - x_2\lambda)(\mu - \lambda)}$. Correspondingly the marginal consumer x_2 is determined by $u_{\text{ISP2}}(x_2) = u_{\text{C2}}(x_2)$, i.e.,

$$V(\lambda) - tx_2 - F_2 - \frac{d}{\mu - x_2\lambda} = V(\lambda) - t(1 - x_2) - F_2 - \frac{d\mu}{(\mu - x_2\lambda)(\mu - \lambda)} \tag{8}$$

which leads to a higher market share for the ISP ($x_2 > \frac{1}{2}$) than content provider C ($1 - x_2 < \frac{1}{2}$).

The ISP maximizes its profit by solving

$$\max_{F_2, p_2} \ \pi_{\text{ISP2}} = F_2 + x_2 \lambda r_{\text{ISP}}$$

$$\begin{aligned} \text{s.t.} \quad & u_{\text{ISP2}}(\tilde{x}) \ge 0, \quad 0 \le \tilde{x} \le x_2 \\ & u_{\text{C2}}(\tilde{x}) \ge 0, \quad x_2 \le \tilde{x} \le 1 \\ & \pi_{\text{ISP2}} - \pi_{\text{ISP1}} \ge 0 \\ & \pi_{\text{C2}} - \pi_{\text{C4}} \ge 0 \end{aligned} \tag{9}$$

where, just as in formulation (7), the first two constraints are consumers' participation constraints and the last two are incentive compatibility constraints for the ISP and content provider C. Note that if Outcome 2 holds, then the ISP does not generate any revenue from priority delivery, since the only content that is prioritized is from its strategic partner. In this scenario, in order to ensure C's incentive compatibility constraint to hold true, the ISP will need to ensure that C's profit under this outcome when it does not pay the ISP (so that its content gets lower priority for delivery than the ISP's content) is at least as high as it is under Outcome 4, when C pays to ensure that the delivery of its content will not be relatively degraded with respect to the ISP's own content.

Outcome 2 is a valid equilibrium only if $r_{\text{ISP}} > r_{\text{C}} + \frac{t}{\lambda}(1 - 2x_3)$, i.e. the ISP can have an incentive to offer this pricing/prioritization policy only if it is also the "sufficiently" more profitable content provider (since the online content provider's marginal cost of providing content can be approximated to zero, the relative profitability of the two content providers can be measured from their revenues). If however $r_{\text{ISP}} \le r_{\text{C}} + \frac{t}{\lambda}(1 - 2x_3)$ [3], Outcome 2 is dominated by other scenarios.

<u>Outcome 3:</u> The ISP does not prioritize its own content and content provider C pays for the preferential delivery ($I_{\text{ISP}} = 0, I_{\text{C}} = 1$).

As opposed to Outcome 2, in Outcome 3 it is the data packets from content provider C that are transmitted with higher priority with a waiting time of $\frac{1}{\mu - (1 - x_3)\lambda}$ while data packets from the ISP are transmitted with lower priority with waiting time of $\frac{\mu}{\left[\mu - (1 - x_3)\lambda\right](\mu - \lambda)}$. Correspondingly the marginal consumer under Outcome 3, x_3 is determined by $u_{\text{ISP3}}(x_3) = u_{\text{C3}}(x_3)$, i.e.,

$$V(\lambda) - tx_3 - F_3 - \frac{d\mu}{\left[\mu - (1 - x_3)\lambda\right](\mu - \lambda)} = V(\lambda) - t(1 - x_3) - F_3 - \frac{d}{\mu - (1 - x_3)\lambda} \tag{10}$$

which leads to a lower market share for the ISP ($x_3 < \frac{1}{2}$) than content provider C ($1 - x_3 > \frac{1}{2}$).The ISP maximize its profit by solving

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[3] We assume that when the ISP is indifferent between two different outcomes (i.e. between Outcome 2 and Outcome 4, or between Outcome 3 and Outcome 4), it chooses Outcome 4.

$$\max_{F_3, p_3} \ \pi_{\text{ISP3}} = F_3 + x_3 \lambda r_{\text{ISP}} + \left(1 - x_3\right) \lambda p_3$$

$$\begin{aligned} \text{s.t.} \quad & u_{\text{ISP3}}(\tilde{x}) \geq 0, \quad 0 \leq \tilde{x} \leq x_3 \\ & u_{\text{C3}}(\tilde{x}) \geq 0, \quad x_3 \leq \tilde{x} \leq 1 \\ & \pi_{\text{ISP3}} - \pi_{\text{ISP4}} \geq 0 \\ & \pi_{\text{C3}} - \pi_{\text{C1}} \geq 0 \end{aligned} \tag{11}$$

Now, in order to satisfy its own incentive compatibility constraints, the ISP has to make sure that its profits under Outcome 3, when C pays and the delivery of its own content is degraded with respect to that of C, is at least as high as under Outcome 4, when C pays and the content from both providers receive equal priority. Note that depending on the relative magnitudes of the average per-consumer advertising revenue that is generated by the ISP and C, the ISP will sometimes *willingly* degrade delivery of its own content (Outcome 3) in order to extract the surplus from the advertising revenue that C generates from its bigger market share. The additional surplus extracted from C might be enough to more than compensate the loss of revenue from the loss of market share (compared to Outcome 4). In order to satisfy C's incentive compatibility constraints, the ISP has to ensure that by paying and getting priority delivery of its packets, C ensures that its profit is at least as high as under Outcome 1, when it does not pay and the delivery of its content does not receive priority (but is not degraded either).

Analogous to Outcome 2, Outcome 3 is a valid equilibrium only if $r_{\text{C}} > \left(\frac{1 - x_3}{1/2 - x_3}\right) r_{\text{ISP}} + \frac{t}{\lambda}\left(1 - 2x_3\right)$, i.e. the ISP can have an incentive to offer this pricing policy only if it is the "sufficiently" less profitable content provider. Conversely, if $r_{\text{C}} \leq \left(\frac{1 - x_3}{1/2 - x_3}\right) r_{\text{ISP}} + \frac{t}{\lambda}\left(1 - 2x_3\right)$, Outcome 3 is dominated by other scenarios. We also note that since the independent content provider is more effective in generating revenue, the ISP can credibly enforce this pricing/prioritization strategy where content provider C has reasons to believe that the ISP will relative degrade its own content's delivery, since by doing so, it can extract part of the surplus that the content provider C will generate from the enhanced market share.

<u>Outcome 4:</u> Here, the ISP prioritizes its own content and content provider C pays for the preferential delivery ($I_{\text{ISP}} = I_{\text{C}} = 1$) to ensure that its own packets do not get degraded with respect to those of the ISP as in Outcome 2.

In Outcome 4, data packets from *both* the ISP and content provider C get "preferential" delivery – in other words, delivery of neither content is degraded with respect to the other. Therefore, packets from provider face the same waiting time $\frac{1}{\mu - \lambda}$. So the marginal consumer x_4 is determined by $u_{\text{ISP4}}\left(x_4\right) = u_{\text{C4}}\left(x_4\right)$, i.e.,

$$V\left(\lambda\right) - t x_4 - F_4 - \frac{d}{\mu - \lambda} = V\left(\lambda\right) - t\left(1 - x_4\right) - F_4 - \frac{d}{\mu - \lambda} \tag{12}$$

which leads to $x_4 = \frac{1}{2}$. The ISP's profit maximization problem under Outcome 4 is:

$$
\begin{aligned}
\max_{F_4, p_4}\ & \Pi_{\text{ISP4}} = F_4 + \frac{1}{2}\lambda r_{\text{ISP}} + \frac{1}{2}\lambda p_4 \\
\text{s.t.}\ & u_{\text{ISP4}}(\tilde{x}) \geq 0, \quad 0 \leq \tilde{x} \leq x_4 \\
& u_{\text{C4}}(\tilde{x}) \geq 0, \quad x_4 \leq \tilde{x} \leq 1 \\
& \pi_{\text{ISP4}} - \pi_{\text{ISP3}} \geq 0 \\
& \pi_{\text{C4}} - \pi_{\text{C2}} \geq 0
\end{aligned}
\tag{13}
$$

For the ISP, the scenario is the reverse of Outcome 3, and hence, to maintain incentive compatibility, the ISP has to ensure that its profit under Outcome 4 is at least as high as under Outcome 3. For content provider C, there remains an incentive to pay the ISP only if by doing so (and thereby not have the delivery of its content degraded with respect to those of the ISP as in Outcome 2), it can generate profits that are as high as under Outcome 2.

With respect to the regions outlined in Figure 4, Outcome 4 is the equilibrium in the region in between that of Outcome 2 and Outcome 3. This is where the profitability of the ISP and the content provider is relatively "comparable". We note that the fixed fee is higher compared to that in Outcomes 2 and 3, and the ISP now gets relatively more of its profit from the consumers than from the content providers as compared to Outcomes 2 and 3.

Proposition 1 summarizes the results of equilibrium of the game.

Proposition 1 (Equilibrium of the game): There are three possible equilibria of the game.

Under Case A $r_{\text{C}} < r_{\text{ISP}} - \frac{t}{\lambda}(1-2x_3)$, Outcome 2 is the equilibrium;

Under Case B $r_{\text{C}} > \left(\frac{1-x_3}{1/2-x_3}\right) r_{\text{ISP}} + \frac{t}{\lambda}(1-2x_3)$, Outcome 3 is the equilibrium;

Under Case C $r_{\text{ISP}} - \frac{t}{\lambda}(1-2x_3) \leq r_{\text{C}} \leq \left(\frac{1-x_3}{1/2-x_3}\right) r_{\text{ISP}} + \frac{t}{\lambda}(1-2x_3)$, Outcome 4 is the equilibrium. Case C can be further divided into two sub-cases:

Under Case C1 $r_{\text{ISP}} - \frac{t}{\lambda}(1-2x_3) \leq r_{\text{C}} \leq \left(\frac{1-x_3}{1/2-x_3}\right) r_{\text{ISP}}$, $p_{41} = (1-2x_3) r_{\text{C}}$, $\pi_{41} = V(\lambda) - \frac{1}{2}t - \frac{d}{\mu-\lambda} + \frac{1}{2}\lambda r_{\text{ISP}} + \left(\frac{1}{2} - x_3\right)\lambda r_{\text{C}}$;

under Case C2 $\left(\frac{1-x_3}{1/2-x_3}\right) r_{\text{ISP}} \leq r_{\text{C}} \leq \left(\frac{1-x_3}{1/2-x_3}\right) r_{\text{ISP}} + \frac{t}{\lambda}(1-2x_3)$, $p_{42} = r_{\text{ISP}}$, $\pi_{42} = V(\lambda) - \frac{1}{2}t - \frac{d}{\mu-\lambda} + \lambda r_{\text{ISP}}$.

Proof: Complete derivations of the proofs lie with the authors.

We note that though x_3 appears in the expressions in Proposition 1, it is completely determined by the external parameters μ, λ, d and t, and hence is not endogenously determined.

Figure 4 shows graphically the effect of the relative magnitudes of r_C and r_{ISP} on the final equilibrium. We can think of the graph being divided into two areas by the line $r_C = r_{ISP}$, with the bottom half corresponding to the case when the vertically integrated ISP is more profitable in generating advertising revenue than its pure play competitor, while the top half represents the opposite scenario. The figure can be divided into three main regions, which we denote as Case A, B and C respectively, and Case C can be further divided into two regions C1 and C2. The shaded region in the bottom half of the quadrant represents Case A, or Outcome 2. The other shaded region, which is in the top half of the quadrant represents Case B, or Outcome 3. The remaining area represents Case C, or Outcome 4.

As noted earlier, Case A or Case B occurs only when the relative revenue generation rates r_C and r_{ISP} are "sufficiently" different from one another (the exact magnitude of the difference necessary is given by the straight lines that demarcate the different regions). When the revenue generation rates are relatively "comparable", Outcome 4, or Case C, dominates. In this scenario, the ISP can credibly ask for compensation from its competitor content provider as an assurance for not prioritizing its (the ISP's) own content over that of content provider C. It is instructive to compare this outcome with that of Case B. In the latter case, the ISP, which is relatively much less profitable in generating revenue from its own content than its competitor, finds it to its advantage to prioritize its competitor's content relative to its own and then extract the surplus from the latter which has a higher market share, than to give its content the same priority as that of its competitor (which it does under Case C, when the ISP is relatively more profitable).

The two regions in Case C, C1 and C2, warrant a separate explanation. The level of the priority access fee *p* is determined by two constraints: (1) it has to be low enough to attract content provider C to pay and (2) as opposed to Case B discussed above, *p* has to be low enough so that the ISP does not have the incentive to degrade the delivery of its own content. Case C1 denotes the region where constraint 1 binds, while Case C2 denotes the region where constraint 2 binds.

We end this section with a discussion of the implications of Case A and B. Under Case A, the ISP prioritizes its own content at the expense of its competitor, who prefers not to pay for that privilege. The ISP thus gets an advantage over its competitor without the requirement of a comparable rent, and this is something that should definitely be of interest to a policymaker deliberating on this issue, since such an arrangement might be tantamount to unfair competition. Under Case B, we have an outcome which looks counter-intuitive at first sight: the ISP deliberately de-prioritizes its own content with respect to its competitor in exchange for a fee. As the discussion in the previous paragraph indicates, this outcome is actually credible: the ISP gains more from the fee from its competitor (who has a higher market share) than it would have generated from the advertising revenue of its own content (and commanding the same market share) by delivering its own content with the same priority as that of its competitor.

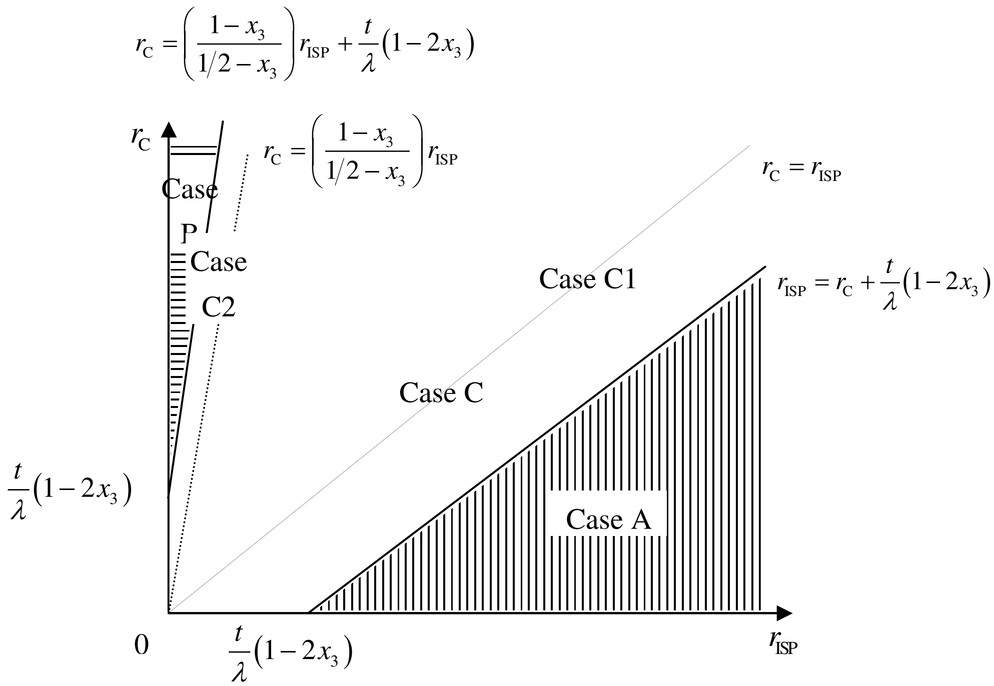

Figure 4. *The equilibria with vertical integration*

5 THE WELFARE EFFECT OF NET NEUTRALITY WITH VERTICAL INTEGRATION

We have already observed that given the choice, the ISP will never opt for abiding by the principles of net neutrality – in other words, unless enforced, net neutrality will never be a natural outcome of the game. It is imperative therefore from a regulatory perspective to find out whether it is in the best interests of the other players (the content providers and the consumers), as well as in terms of the total social welfare, to regulate enforcement of network neutrality. This section is devoted to that discussion – we discuss the impact of net neutrality (or its abolishment) on the payoffs to the three players and the overall welfare. Proposition 2 summarizes the findings.

Proposition 2 (The welfare impact of net neutrality): Comparing the results of NNN to NN, we get the following:

Under Case A (when $r_C < r_{ISP} - \frac{t}{\lambda}(1-2x_3)$) and Case B (when $r_C > \left(\frac{1-x_3}{1/2-x_3}\right) r_{ISP} + \frac{t}{\lambda}(1-2x_3)$), both consumer surplus and social welfare increase.

Under Case C (when $r_{ISP} - \frac{t}{\lambda}(1-2x_3) \le r_C \le \left(\frac{1-x_3}{1/2-x_3}\right) r_{ISP} + \frac{t}{\lambda}(1-2x_3)$), both consumer surplus and social welfare remain unchanged.

The expressions of consumer surplus and social welfare are provided in Table 1, which shows the comparison of the prices charged by the ISP, the profits of the ISP and that of the content provider C, the consumer surplus and the total social surplus under NN and in the three potential equilibria under NNN (which we denoted earlier as Cases A, B and C respectively). Case C is in turn divided into two subcases

C1 and C2, as discussed in the previous section. Table 1 also shows the result of comparing the magnitude of these output variables under the different scenarios of NNN to that under NN, and in all the cases, we establish how the expressions compare regardless of input parameter values.

As can be seen from Table 1, the consumers' access fees are lower with NNN than with NN under Cases A and B and unchanged under Case C. The corresponding consumer surpluses are higher under Cases A and B as compared to NN, and unchanged under Case C. Similarly, the total social welfare with vertical integration increases with NNN under Cases A and B as compared to NN, while it is unchanged in Case C.

The vertically integrated ISP's surplus is always higher under NNN, and therefore the ISP will always prefer NNN over NN.

The expressions in Table 1 establish that the content provider C has either the same surplus (Case B) or is worse off under NNN. Interestingly, content provider C has the same surplus in Case B that it has under NN, even though it has a higher market share than under NN – this is so because the ISP is able to extract the additional surplus from C completely through the priority access fee. In Case A, content provider C has a lower market share than under NN, and consequently a lower surplus. In Case C, content provider C and the ISP have the same market share as under NN, but as a result of the priority access fee, content provider C's net surplus is lower than under NN.

6 CONCLUSION

The issue of net neutrality has wide implications for the ways that online content will be created, delivered and consumed in the near future. If the local ISP has control over the infrastructure that delivers this online content to end users, it can effectively regulate the choices of the end consumers. This is possible since the 'pipe' by which the content is delivered to the end users has limited bandwidth, and therefore prioritizing some specific content for delivery automatically leads to increased delay for the rest of the non-prioritized content. Even though a lot of literature exists that analyzes the various facets of the net neutrality problem, most of the analyses focus on the legal and regulatory perspectives of the debate. In contrast, the research by Economides and Tag (2007) or Cheng , et al. (2009) represent some of the few papers that concentrate on the economic issues surrounding the debate, and analyze them rigorously within an analytical framework. This paper contributes to that stream of economic literature, by looking into the incentives of the various players involved and analyzing them using a game-theoretic model, looking specifically into the issue of vertical integration between the ISP and a content provider.

We find that whether social welfare increases or decreases crucially depends on whether the ISP is integrated with the more or less effective content provider (effectiveness in this case being defined as the ability to generate advertising revenue from the consumer base). If the vertically integrated firm is relatively less effective in generating revenue from its content, we find that for a range of parameter values, the social welfare decreases as compared to a situation when there is no vertical integration. On the other hand, social welfare can actually increase if the ISP is vertically integrated with the more effective content provider. But in either case, the competing content provider is often left worse off (and is never better off).

Future research can look at the effects of vertical integration in the long run, and explore whether the competing content providers are driven out of the market. Other possible areas of exploration include relaxing the constraint of market coverage, or allowing for different types of online content from different providers.

Table 1: Comparison of various economic outcomes of interest under NN and NNN

(The ***bold and italicized*** text shows how those economic outcomes change when moving from NN to NNN)

	NN (Benchmark)	**NNN (Case A: Outcome 2 – Only the ISP's content is prioritized)**	**NNN (Case B: Outcome 3 – Only C's content is prioritized)**	**NNN (Case C: Outcome 4 – Both the ISP and C's content are equally prioritized)**	
				Case C1	**CaseC2**
F	$V(\lambda)-\frac{t}{2}-\frac{d}{\mu-\lambda}$	$V(\lambda)-tx_2-\frac{d}{\mu-x_2\lambda}$ ***Lower***	$V(\lambda)-t(1-x_3)-\frac{d}{\mu-(1-x_3)\lambda}$ ***Lower***	$V(\lambda)-\frac{t}{2}-\frac{d}{\mu-\lambda}$ ***Unchanged***	$V(\lambda)-\frac{t}{2}-\frac{d}{\mu-\lambda}$ ***Unchanged***
p	N/A	N/A	$\left(\frac{1/2-x_3}{1-x_3}\right)r_{\text{C}}$	$(1-2x_3)r_{\text{C}}$	r_{ISP}
ISP's Profit	$V(\lambda)-\frac{t}{2}-\frac{d}{\mu-\lambda}+\frac{1}{2}\lambda r_{\text{ISP}}$	$V(\lambda)-tx_2-\frac{d}{\mu-x_2\lambda}+x_2\lambda r_{\text{ISP}}$ ***Better off***	$V(\lambda)-t(1-x_3)-\frac{d}{\mu-(1-x_3)\lambda}+\left(\frac{1}{2}-x_3\right)\lambda r_{\text{C}}+x_3\lambda r_{\text{ISP}}$ ***Better off***	$V(\lambda)-\frac{t}{2}-\frac{d}{\mu-\lambda}+\frac{1}{2}\lambda r_{\text{ISP}}+\left(\frac{1}{2}-x_3\right)\lambda r_{\text{C}}$ ***Better off***	$V(\lambda)-\frac{t}{2}-\frac{d}{\mu-\lambda}+\lambda r_{\text{ISP}}$ ***Better off***
Content Provider C's Profit	$\frac{1}{2}\lambda r_{\text{C}}$	$(1-x_2)\lambda r_{\text{C}}$ ***Worse off***	$\frac{1}{2}\lambda r_{\text{C}}$ ***Unchanged***	$x_3\lambda r_{\text{C}}$ ***Worse off***	$\frac{1}{2}\lambda(r_{\text{C}}-r_{\text{ISP}})$ ***Worse off***
Consumer Surplus	$\frac{t}{4}$	$t\left(x_2^2-x_2+\frac{1}{2}\right)$ ***Better off***	$t\left(x_3^2-x_3+\frac{1}{2}\right)$ ***Better off***	$\frac{t}{4}$ ***Unchanged***	$\frac{t}{4}$ ***Unchanged***
Social Welfare	$V(\lambda)-\frac{t}{4}-\frac{d}{\mu-\lambda}+\frac{1}{2}\lambda r_{\text{ISP}}+\frac{1}{2}\lambda r_{\text{C}}$	$V(\lambda)+t\left(x_2^2-2x_2+\frac{1}{2}\right)-\frac{d}{\mu-x_2\lambda}+x_2\lambda r_{\text{ISP}}+(1-x_2)\lambda r_{\text{C}}$ ***Increased***	$V(\lambda)-t\left(\frac{1}{2}-x_3^2\right)-\frac{d}{\mu-(1-x_3)\lambda}+x_3\lambda r_{\text{ISP}}+(1-x_3)\lambda r_{\text{C}}$ ***Increased***	$V(\lambda)-\frac{t}{4}-\frac{d}{\mu-\lambda}+\frac{1}{2}\lambda r_{\text{ISP}}+\frac{1}{2}\lambda r_{\text{C}}$ ***Unchanged***	$V(\lambda)-\frac{t}{4}-\frac{d}{\mu-\lambda}+\frac{1}{2}\lambda r_{\text{ISP}}+\frac{1}{2}\lambda r_{\text{C}}$ ***Unchanged***

Appendices:

Appendix A: List of notations

x : the marginal consumer indifferent between content providers ISP and C
$\tilde{x}$: an arbitrary consumer on $[0,1]$
r_{ISP} : the ISP's revenue rate per packet request for content
r_{C} : content provider C's revenue rate per packet request for content
p: the per packet price for priority data packet transmission
I_{ISP} , I_{C} : the ISP's and content provider C's service choices
λ : Poisson arrival rate of content requested from each consumer in packets per unit of time
t : fit cost parameter for an end consumer away from the ideal content
$V(\lambda)$: the gross value function of retrieving content for each consumer; concave and twice-differentiable
d: customers' delay cost parameter (i.e., congestion cost) per unit of time
$u_{\text{NN\_ISP}}$, $u_{\text{NN\_C}}$, $u_{\text{ISP}i}$, $u_{\text{C}i}$: consumers' utility function
F: the fixed fee per unit of time charged by the broadband provider to the end consumers
μ : capacity of the broadband provider in packets per unit of time
x_{NN} : the marginal consumer indifferent between ISP and content provider C under net neutrality
x_i : the marginal consumer indifferent between ISP and content provider C in Outcome $i = 1,2,3,4$ under no net neutrality
$\pi_{\text{ISP}i}$: ISP's profit in Outcome $i = 1,2,3,4$
$\pi_{\text{C}i}$: Content provider C's profit in Outcome $i = 1,2,3,4$

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