# Policy, Pricing and Investment in a Two-Tier Internet

*Barrie R. Nault* †

*and*

*Steffen Zimmermann*††

†Haskayne School of Business
University of Calgary
nault@ucalgary.ca

††School of Management
University of Innsbruck
steffen.zimmermann@uibk.ac.at

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## Abstract

*The open Internet is plagued by congestion and security problems that restrict the development of sophisticated Internet-based services. Telecommunication and technology providers have proposed a fee-based fast-lane Internet to overcome these problems. This is opposed by network-neutrality proponents that believe the open Internet will suffer reduced infrastructure investment. In our model firms choose which Internet to use and production levels, an Internet Service Provider (ISP) sets fees for fast-lane Internet access, and a policy-maker chooses whether to allow a fast-lane Internet and to require a portion of ISP profit be invested into the open Internet. We find firms with higher intensity of Internet use convert to the fast-lane Internet, and the ISP chooses a fixed fee pricing. The fast-lane Internet increases welfare through higher aggregate output and lower negative externalities. Finally, the policy-maker mandates investment in the open Internet only if investment sufficiently reduces firm congestion costs and negative externalities.*



Keywords: Incentives, Technology Conversion, Internet, Privatization.

# 1 Introduction

Present regulation supports the Internet as a public network with open access for commercial and personal use where all transferred packages are treated equally (FCC, 2010). This open access is often referred to as network-neutrality, a concept where infrastructure owners are not allowed to prioritize traffic and consequently do not have control over the content and applications that run through their network (Picot & Krcmar, 2011). The problem for policy is that the current open Internet is subject to congestion and security threats. Without traffic prioritization ISPs cannot offer fee-based quality of service (QoS) agreements, which restricts their incentive to build more infrastructure. Firms have little incentive to develop sophisticated Internet-based services such as cloud services: information technology (IT) that is used on-demand over the Internet. Barriers to adopting cloud services are congestion-created delays and security problems including data loss, phishing and cyber-attacks as well as availability and performance (e.g., IDC, 2010; Trigueros-Preciado, Perez-Gonzales & Solana-Gonzales, 2013). Thus, cloud services require a fast and reliable Internet. We use cloud services as a running example throughout the paper.

To deal with congestion and security problems and to promote greater investment in infrastructure, some ISPs and other large technology providers have proposed a fast-lane Internet that represents a logically or physically separate tier where an ISP can prioritize traffic and thus offer fee-based QoS agreements that are distinguishable from usual broadband Internet access. Network-neutrality proponents argue that a two-tier Internet would hinder innovation, and motivate underinvestment in infrastructure by ISPs to create a scarcity of bandwidth in order to charge higher basic connection fees. Consequently, network-neutrality proponents believe this would lead to a decrease in social welfare.

There are two primary policy considerations when examining the impact of a two-tier Internet on welfare. One is productivity in the economy that generates economic value. Productivity from the open Internet comes from three channels. The first channel is business-to-consumer (B2C) e-commerce, essentially treating the Internet as a retail channel for physical and information goods. The second channel is business-to-business (B2B) e-commerce that uses the Internet as the base layer for cloud computing and interorganizational systems (IOS). The third channel is internal to the firm – many firms use the Internet as the base layer of their internal communications such as virtual private networks (VPNs). Another consideration is the impact of a two-tier Internet on the social value individuals receive. This social value comes from e-mail, video streaming, social networking and information retrieval. Both productivity and social value are compromised by increasing congestion and security threats in the open Internet. These threats reduce the adoption, benefit and incentive for investments in new value added Internet-based services.

**Our Focus:** To determine if a two-tier Internet can increase welfare, we construct a model with a straightforward policy mechanism and examine firm conversion to a fast-lane Internet and ISP pricing. We begin using an approach whereby firms – that can represent a cross-section of the economy – differ in their intensity of Internet use. Firms make production decisions and decide whether to convert to the fast-lane Internet. In this production setting, firms may use the Internet to provide Internet-based services to consumers either as a retail channel or for customer support, for cloud computing and IOS support between firms (co-ordination and collaboration), or as the base layer for internal communication. From these decisions we construct a choice of basic pricing mechanisms for a monopoly ISP that owns the last mile facilities. The ISP's pricing leads to its profits, as well as output and profits for firms and industry in aggregate. Then we incorporate a policy-maker that can choose first whether to restrict regulation and allow a fast-lane Internet, and second whether to require the ISP invest an amount of its fast-lane Internet revenues into its open Internet offering. The policy-maker considers the effects of its policy on firm output, which in turn affects consumer and producer surplus as well as negative externalities in the open Internet. Thus, our policy combination allows for a fast-lane Internet in which the ISP can profit as well as a mechanism to ensure investments in the open Internet to safeguard its viability.

We find that firms with higher intensity of Internet use convert, and those with lower intensity of Internet use do not. Next, the ISP chooses a fixed fee rather than usage-based pricing for the fast-lane Internet. Consequently, aggregate output and producer surplus are increased and negative externalities on the open Internet are decreased – yielding a positive impact on social welfare of the fast-lane Internet. Finally, the investment mechanism whereby a portion of ISP profit is invested in the open Internet can only increase welfare when the direct effects of investment sufficiently reduce individual firm congestion costs and negative externalities across the open Internet. For a discussion of our contribution to the related literature see Appendix A of the online version (http://www.uibk.ac.at/iwi2/tticist).

## 2 Notation and Assumptions

Our assumptions relate the firm's efficiency in their production technology to their profits, their congestion costs and the negative externalities they cause. We begin with our assumption about how firms differ and what policy-makers can know.

**Assumption 1 (Observability)** *Firms differ in how intensively their production technology uses the Internet, and an individual firm's intensity of use is not verifiable.*

Using the cloud services example, the intensity of Internet use in a firm's production technology can also be interpreted as the intensity of use of on-demand cloud services over the Internet, making available IT that is required to produce the firm's output.

Firms are heterogeneous in their production technology. We denote individual firm production technology as $\theta$ which is normalized to be in the interval $[0, 1]$. Thus, $f(\theta) > 0 \; \forall \; \theta \in [0, 1]$, $F(0) = 0$ and $F(1) = 1$. The production technology $\theta$ represents increasing intensity of Internet use per unit of output so that firms with a $\theta = 0$ are the firms that most efficiently use the Internet, and consequently are the firms with the lowest intensity of Internet use per unit of output. Firms with $\theta = 1$ are the firms that least efficiently use the Internet, and consequently have the highest intensity of Internet use per unit of output. In terms of our example, this means that firms that most efficiently use the Internet use on-demand cloud services less in producing output, whereas firms that less efficiently use the Internet use more cloud services and thus have higher intensity of Internet use per unit of output. We treat $\theta$ as uniformly distributed over its support. This incurs little loss of generality as $\theta$ can be scaled as needed. The policy-maker knows the distribution and range of $\theta$.

We represent firm output by $x \in \mathcal{R}^+$ and in absence of a fast-lane Internet aggregate output is $X(\cdot) = \int_0^1 x(\theta)f(\theta)d\theta$ where individual firm output can depend on $\theta$. Thus, a firm's usage of the Internet is defined as the intensity of Internet use per unit of output times output, $\theta\ x$. Output is verifiable by the policy-maker through income tax filings or other legal mechanisms. However, as firms using the Internet are based in a variety of different industries and have different business models, output is not perfectly correlated with – and therefore cannot be used to infer – intensity of Internet use.

**Firm Profits:** Firm profits using the Internet depend on its production technology, $\theta$, and its output, $x$. We denote this profit function by $PR(\theta, x)$, which is bounded from below, $PR(\theta, 0) = 0$. Using our reduced form, we take firm profits as increasing in output to some arbitrary output level, $\bar{x}_\theta$, which may depend on the firm's production technology, and concave. We also assume that with all things equal profits are lower for firms with a more inefficient production technology. Using our cloud services example, the more on-demand cloud services are used to produce a unit of output, the higher are the unit costs – cloud services are usually paid-per-use – and consequently the lower the profits.

**Assumption 2 (Profits)**

$$\frac{\partial PR(\theta, x)}{\partial x} \geq 0 \ \ \forall\, 0 \leq x \leq \bar{x}_\theta, \qquad \frac{\partial^2 PR(\theta, x)}{\partial x^2} < 0 \quad and \quad \frac{\partial PR(\theta, x)}{\partial \theta} < 0.$$

This reduced form profit function abstracts from issues of market structure and whether markets are one- or two-sided, and is meant to be general enough to represent firm profits in industries with various degrees of competition so long as the competition is not strategic.

**Externalities and Congestion:** Open Internet use by firms generates negative externalities for other users that come from congestion and compromised security. Negative externalities $q(\theta, X, I) \in \mathcal{R}^+$ depend on the production technology – its intensity of Internet use, $\theta$, the aggregate output in the open Internet, $X = \int_0^1 x(\theta, I)f(\theta)d\theta$, that we define in more detail later, and the investments in the infrastructure of the open Internet, $I \in [0, \bar{I}]$. We assume firms generate negative externalities that are increasing and convex in aggregate output (the latter due to dynamics of congestion and security), and are increasing in a firm's intensity of Internet use. Moreover, we assume that the negative externalities are decreasing in the investments in the open Internet as these investments increase capacity.

**Assumption 3 (Negative Externalities)**

$$\frac{\partial q(\theta, X, I)}{\partial X}, \frac{\partial^2 q(\theta, X, I)}{\partial X^2}, \frac{\partial q(\theta, X, I)}{\partial \theta} > 0 \quad \textit{and} \quad \frac{\partial q(\theta, X, I)}{\partial I} < 0.$$

Negative externalities have social impacts. Defining $Q(\cdot)$ as aggregate negative externalities from using the open Internet, we define total social costs from negative externalities as $\omega(Q(\cdot))$ and increasing in aggregate negative externalities, $d\omega(Q(\cdot))/dQ > 0$.

Open Internet use by firms results in negative externalities for other users and at the same time in congestion costs for each individual firm. These congestion costs depend on the same arguments as the negative externalities for other users, and we denote these congestion costs by $K(\theta, X, I)$. Similar to negative externalities, we assume that these costs are increasing and convex in aggregate output and in the intensity of Internet use, and are decreasing in the investments in the open Internet.

**Assumption 4 (Congestion Costs)**

$$\frac{\partial K(\theta, X, I)}{\partial X}, \frac{\partial^2 K(\theta, X, I)}{\partial X^2}, \frac{\partial K(\theta, X, I)}{\partial \theta}, \frac{\partial^2 K(\theta, X, I)}{\partial \theta^2} > 0 \quad \textit{and} \quad \frac{\partial K(\theta, X, I)}{\partial I} < 0.$$

The last elements of Assumptions 3 and 4 relate to the response of negative externalities and congestion to open Internet investments. As we will see later, these are direct effects of investment in the open Internet, and indirect effects through changes in firm output.

**Conversion to Fast-lane Internet:** Firms can convert to a fast-lane Internet where congestion and security externalities are eliminated, or at least are inconsequential. The fast-lane Internet is provided by a monopoly ISP that owns the last-mile facilities and that is vertically integrated with a network service provider (NSP) that owns broadband Internet access. Vertically integrated ISPs and NSPs comprise the majority of broadband Internet connections. The ISP sets a fixed fee $S$ and a marginal fee $s$ that depends on the usage, $\theta\ x$, for the fast-lane Internet. The ISP faces fixed costs of setting up the fast-lane Internet that we represent by $F$. These fixed costs might depend on whether the fast-lane Internet is physically or logically separate from the open Internet, or even a combination of the two.

**Production Technology and Output:** There are relationships between the production technology's intensity of Internet use and output that affect our measures of profits, negative externalities, and congestion costs. These relationships are fundamental to our results: firms with production technology that has greater intensity of Internet use *(a)* have no substantive change of profit per unit of output; *(b)* have greater negative externalities per unit of output; and *(c)* have moderately greater congestion costs per unit of aggregate output and thus per unit of output. Additionally, the congestion costs per unit of aggregate output and thus per unit of output are decreasing with an increase in investment in the open Internet.

**Assumption 5 (Cross Effects)**

$$(a):\quad \frac{\partial^2 PR(\theta,x)}{\partial\theta\partial x}\simeq 0,\quad (b):\quad \frac{\partial^2 q(\theta,x)}{\partial\theta\partial x}>0,\quad (c):\quad \frac{\partial^2 K(\theta,X,I)}{\partial\theta\partial X}>0,\frac{\partial^2 K(\theta,X,I)}{\partial I\partial X}<0.$$

The assumption on profit reflects that firms have an intensity of Internet use (e.g., how efficiently they use fee-based cloud services) as an element of their production technology, and choose a short-run (i.e., one year) factor input mix to generate a level of output at a minimum cost, and this differs between firms and industries. Thus, there is no systematic relationship between intensity of Internet use and the marginal costs of the next unit of output, and in equilibrium marginal costs should be similar across firms. The assumptions on negative externalities and congestion costs reflects that firms which have a higher intensity of Internet use have greater negative externalities from additional congestion and security as output is expanded, and this also applies to the congestion costs they face as firms. For example, firms that less efficiently use cloud services are likely to require more bandwidth and create more security vulnerabilities with an additional unit of output than firms that use cloud services more efficiently. Finally, in the open Internet with greater investment, the impact on congestion firms face from expanding output is lessened as there is a higher bandwidth and more secure infrastructure.

**Policy:** The policy-maker makes two decisions. First, network-neutrality regulation can be restricted to allow the ISP to offer a fast-lane Internet. Second, the ISP may be required to invest an amount of its fast-lane Internet revenues, $I$, in its open Internet. These investments directly affect negative externalities, congestion costs and marginal congestion costs as in Assumptions 3 and 4, and indirectly affect firm output. We can define the potential range of these investments as $I \in [0, \int_0^1 (S + s\theta x) f(\theta) d\theta - F]$, where the term under integration is the revenue the ISP receives from firms that convert to the fast-lane Internet, so that the maximum amount of required investment is no greater than the ISP profit. To the degree that it is useful for instruments, the policy-maker can observe and verify which Internet the firm is using, and each firm's level of output.

# 3 Use of a Two-Tier Internet

The policy-maker decides whether to allow a monopoly ISP to set up a fast-lane Internet and whether to require the ISP to invest in the open Internet. Then, the ISP decides whether to charge firms a fixed fee or a usage-based fee for access to the fast-lane Internet, and firms decide whether to convert. We work backwards and examine first the firms' production decisions and their choice of whether to convert. Then we model the ISP's pricing problem, and subsequently the policy-maker's investment mechanism decision. The proofs of our lemmas and theorems are in Appendix B of the online version (http://www.uibk.ac.at/iwi2/tticist).

## 3.1 Firms' Production Decisions

**Firms that Convert to the Fast-lane Internet:** For firms that convert to the fast-lane Internet, net profits $\Pi_c(x_c;\theta)$ include the fees for using the fast-lane Internet:

$$\Pi_c(x_c;\theta) = PR_c(\theta, x_c) - S - s\,\theta\,x_c, \tag{1}$$

where for clarity we subscript the reduced form profit function and the resulting output with $c$. As we noted earlier, we abstract from relatively inconsequential congestion costs in the fast-lane Internet. For converting firms, assuming an interior solution, the first-order condition by choice of output is

$$\frac{\partial \Pi_c}{\partial x_c} = \frac{\partial PR_c(\theta, x_c)}{\partial x_c} - s\theta = 0 = \psi_c(\theta, x_c, s), \tag{2}$$

where $\psi_c(\theta, x_c, s)$ implicitly defines the optimal value function $x_c(\theta, s)$. Lemma 1 describes the behaviour of $x_c(\theta, s)$.

**Lemma 1** *For firms that convert to the fast-lane Internet, output is weakly decreasing in their intensity of Internet use, and decreasing in the usage-based fee.*

A special case of Lemma 1 is when the usage-based fee is zero, $s = 0$. In this case the output of converting firms does not change based on their intensity of Internet use. In our cloud services example, firms that use cloud services less efficiently have lower output, and all converting firms reduce output if a usage-based fee is charged to use the fast-lane Internet.

**Firms that do not Convert to the Fast-lane Internet:** For firms that do not convert, net profits include congestion costs from using the open Internet, $\Pi(x;\theta) = PR(\theta, x) - K(\theta, X, I)$. For those non-converting firms, assuming an interior solution, the first-order condition by choice of output is

$$\frac{\partial \Pi}{\partial x} = \frac{\partial PR(\theta, x)}{\partial x} - \frac{\partial K(\theta, X, I)}{\partial X}\frac{\partial X}{\partial x} = \frac{\partial PR(\theta, x)}{\partial x} - \frac{\partial K(\theta, X, I)}{\partial X} f(\theta) = 0 = \psi(\theta, x, I), \tag{3}$$

where $\partial X/\partial x$ is only for a given $\theta$. $\psi(\theta, x, I)$ implicitly defines the optimal value function $x(\theta, I)$. Our next lemma describes the behavior of $x(\theta, I)$.

**Lemma 2** *For firms that do not convert, output is decreasing in its intensity of Internet use and is increasing in the investments in the open Internet.*

In our cloud services example, similar to converting firms, non-converting firms that use cloud services less efficiently choose lower output. In contrast, investments in the open Internet make the use of cloud services more effective, expanding output, regardless of how efficiently the firm uses cloud services.

### 3.2 Industry Response

Each firm maximizes net profit by deciding whether to convert. That is

$$\max\{PR_c(\tilde{\theta}, x_c(\tilde{\theta}, s)) - S - s\,\tilde{\theta}\,x_c(\tilde{\theta}, s), PR(\tilde{\theta}, x(\tilde{\theta}, I)) - K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)\}.$$

We identify the firm with the intensity of Internet use, $\tilde{\theta}$, which is indifferent between converting and not converting by

$$PR_c(\tilde{\theta}, x_c(\tilde{\theta}, s)) - S - s\,\tilde{\theta}\,x_c(\tilde{\theta}, s) - PR(\tilde{\theta}, x(\tilde{\theta}, I)) + K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I) = 0 = \phi(S, s, I, \tilde{\theta}) \quad (4)$$

where $\phi(S, s, I, \tilde{\theta})$ implicitly defines the intensity of Internet use of the indifferent firm $\tilde{\theta}(S, s, I)$. We use $(\cdot)$ for $(S, s, I)$ in the arguments to simplify and shorten our notation. Our first theorem has to be defined for two cases:

**Theorem 1** *Case 1: If $s\,x_c(\tilde{\theta}, s) < \partial K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)/\partial\tilde{\theta}$, then firms with a higher intensity of Internet use convert and firms with a lower intensity of Internet use do not. Case 2: If $s\,x_c(\tilde{\theta}, s) > \partial K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)/\partial\tilde{\theta}$, then firms with a lower intensity of Internet use convert and firms with a higher intensity of Internet use do not.*

In the context of our cloud services example, firms that use cloud services less efficiently convert if the usage-based fees firms pay in the fast-lane Internet are lower than the additional congestion costs they generate in the open Internet. Otherwise, firms that use cloud services more efficiently convert. The following lemma determines the effects of the fixed fee, the usage-based fee, and investments in the open Internet for each of our two cases.

**Lemma 3** *For Case 1, the proportion of firms converting is decreasing in the fixed fee, the usage-based fee and investments in the open Internet. For Case 2, the opposite obtains.*

From these effects it follows directly that the effect of a change in the usage-based fee is precisely the effect of a change in the fixed fee multiplied by output,

$$x_c(\tilde{\theta}, s)\frac{\partial\tilde{\theta}(\cdot)}{\partial S} = \frac{\partial\tilde{\theta}(\cdot)}{\partial s}. \quad (5)$$

### 3.3 ISP's Pricing Decisions

We take the ISP as a monopoly over its potential firm user base. The monopoly ISP sets a two-part price for use of the fast-lane Internet: a fixed fee $S$ and a usage-based fee $s$. The ISP also faces costs of setting a fast-lane Internet, which we take as fixed and denoted by $F$. As we saw in Theorem 1, there are two separate cases based on the relationship between the usage-based fee times the indifferent firm output, $s\ x_c(\tilde{\theta}, s)$, and the additional congestion costs to the open Internet from the indifferent firm, $\partial K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)/\partial\tilde{\theta}$.

**Case 1:** Following Theorem 1 we take that $s\ x_c(\tilde{\theta}, s) \leq \partial K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)/\partial\tilde{\theta}$ so that firms with higher intensity of Internet use convert to the fast-lane Internet. The ISP's profit maximization problem is

$$\begin{aligned}\max_{S,s} \Lambda_1(S, s) &= \max_{S,s}\{S \int_{\tilde{\theta}(\cdot)}^{1} f(\theta)d\theta + s \int_{\tilde{\theta}(\cdot)}^{1} \theta\ x_c(\theta, s) f(\theta)d\theta - I - F\} \\ &\ni\ s\ x_c(\tilde{\theta}, s) \leq \frac{\partial K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)}{\partial\tilde{\theta}}. \end{aligned} \quad (6)$$

Theorem 2 determines the ISP's pricing decision for Case 1.

**Theorem 2** *In Case 1 the ISP charges a positive fixed fee and no usage-based fee.*

**Case 2:** Following Theorem 1 we take that $s\ x_c(\tilde{\theta}, s) > \partial K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)/\partial\tilde{\theta}$ so that firms with lower intensity of Internet use convert to the fast-lane Internet. The ISP's profit maximization problem is

$$\begin{aligned}\max_{S,s} \Lambda_2(S, s) &= \max_{S,s}\{S \int_{0}^{\tilde{\theta}(\cdot)} f(\theta)d\theta + s \int_{0}^{\tilde{\theta}(\cdot)} \theta x_c(\theta, s) f(\theta)d\theta - I - F\} \\ &\ni\ s x_c(\tilde{\theta}, s) > \frac{\partial K(\tilde{\theta}, X(x(\tilde{\theta}, I)), I)}{\partial\tilde{\theta}} \end{aligned} \quad (7)$$

where the limits of integration and the constraint are reversed from Case 1, (6). Theorem 3 determines the ISP's pricing decision for Case 2.

**Theorem 3** *If the impact of the intensity of Internet use on firm output is moderate, then Case 2 is infeasible.*

To sum up, Theorem 3 holds because there is neither an interior solution for the fixed fee nor for the usage-based fee that satisfy the constraint in (7). Thus, Case 1 is the only one that obtains. In terms of our cloud services example, taking the ISPs pricing decision into account, this means that firms that use cloud services less efficiently convert to the fast-lane Internet and firms that are more efficient in their use of cloud services do not.

With the results from Theorems 2 and 3 whereby the ISP only uses a fixed fee and the firms with higher intensity of Internet use convert (i.e., Case 1), we can now restate the ISP's pricing decision as

$$\max_S \Lambda(S) = \max_S \{S \int_{\tilde{\theta}(\cdot)}^{1} f(\theta) d\theta - I - F\}, \tag{8}$$

where $\tilde{\theta}(\cdot)$ represents $\tilde{\theta}(S, s = 0, I)$, i.e., the indifferent firm when the usage-based fee is zero.

## 3.4 Social Welfare

The objective of the policy-maker is to maximize social welfare by choice of the level of investment in the open Internet required from the ISP,

$$\max_I B(I) = \max_I \{CS(X_c(\cdot), X(\cdot)) + PS(\cdot) - \omega(Q(\cdot)) - F\}, \tag{9}$$

where from the prior section the ISP does not employ a usage-based fee, $s = 0$. Social welfare is made up of consumer surplus, $CS(X_c(\cdot), X(\cdot))$, with its arguments being aggregate output of all converting firms $X_c(\cdot)$ and aggregate output of all non-converting firms $X(\cdot)$, producer surplus, $PS(\cdot)$, the total value of negative externalities, $\omega(Q(\cdot))$, and the fixed cost of providing the fast-lane Internet from the ISP, $F$. ISP profit does not enter social welfare as it is a transfer between firms and the ISP.

### 3.4.1 Consumer surplus

Consumer surplus is increasing in its arguments $\partial CS/\partial X_c > 0$ and $\partial CS/\partial X > 0$. The aggregate outputs of converting and non-converting firms are, respectively,

$$X_c(\cdot) = \int_{\tilde{\theta}(\cdot)}^{1} x_c(\theta, 0) f(\theta) d\theta \quad \text{and} \quad X(\cdot) = \int_{0}^{\tilde{\theta}(\cdot)} x(\theta, I) f(\theta) d\theta.$$

Lemma 4 establishes the effects of the investments in the open Internet on aggregate output:

**Lemma 4** *Aggregate output of converting firms is decreasing, and aggregate output of non-converting firms is increasing, in investments in the open Internet.*

### 3.4.2 Producer Surplus

Producer surplus is the sum of the net profits (net of the ISP fixed fee which is a transfer) of converting and non-converting firms:

$$PS(\cdot) = \int_{\tilde{\theta}(\cdot)}^{1} [PR_c(\theta, x_c(\theta, 0))] f(\theta) d\theta + \int_{0}^{\tilde{\theta}(\cdot)} [PR(\theta, x(\theta, I)) - K(\theta, X(\cdot), I)] f(\theta) d\theta.$$

Differentiating the producer surplus with respect to the investments in the open Internet, rearranging terms, using (4), and noting that $s = 0$ we have

$$\begin{aligned} \frac{\partial PS(\cdot)}{\partial I} &= -Sf(\tilde{\theta})\frac{\partial \tilde{\theta}(\cdot)}{\partial I} + \int_{0}^{\tilde{\theta}(\cdot)} \frac{\partial PR(\theta, x(\theta, I))}{\partial x}\frac{\partial x(\theta, I)}{\partial I} f(\theta) d\theta \\ &\quad - \int_{0}^{\tilde{\theta}(\cdot)} \frac{\partial K(\theta, X(\cdot), I)}{\partial X}\frac{\partial X(\cdot)}{\partial I} f(\theta) d\theta - \int_{0}^{\tilde{\theta}(\cdot)} \frac{\partial K(\theta, X(\cdot), I)}{\partial I} f(\theta) d\theta. \end{aligned} \tag{10}$$

Using Lemma 3 the first term is negative. Using Assumption 2 and Lemma 2 the second term is positive. Using Assumption 4 as well as Lemma 4 the third term is negative. From Assumption 4 the fourth term is positive. The first term represents the reduction in profits that come as a consequence of the indifferent firm choosing the open Internet in response to investment. The second term represents the positive effect of investment on profits through the increased output of all non-converting firms, and third term represents the additional congestion costs faced by all non-converting firms resulting from higher aggregate output. The last term represents the reduction in congestion costs due to investment that applies to all firms using the open Internet.

### 3.4.3 Total Value of Negative Externalities

The total value of negative externalities $\omega(Q(\cdot))$ is increasing in its argument $Q(\cdot)$. The aggregate negative externalities of non-converting firms are $Q(\cdot) = \int_0^{\tilde{\theta}(\cdot)} q(\theta, X(\cdot), I) f(\theta) d\theta$. Differentiating with respect to the investments in the open Internet we have

$$\frac{\partial Q(\cdot)}{\partial I} = q(\tilde{\theta}, X(\cdot), I) f(\tilde{\theta}) \frac{\partial \tilde{\theta}(\cdot)}{\partial I} + \int_{0}^{\tilde{\theta}(\cdot)} \frac{\partial q(\theta, X(\cdot), I)}{\partial X}\frac{\partial X(\cdot)}{\partial I} f(\theta) d\theta + \int_{0}^{\tilde{\theta}(\cdot)} \frac{\partial q(\theta, X(\cdot), I)}{\partial I} f(\theta) d\theta. \tag{11}$$

Using Lemma 3 the first term is positive. Using Assumption 3 and Lemma 4, the second term is positive. Using Assumption 3 the third term is negative. The first term represents the increased negative externalities from the indifferent firm choosing to use the open Internet in response to investment, the second term represents the higher negative externalities generated by the output of all non-converting firms induced by investment in the open internet, and the third term represents the direct reduction in negative externalities resulting from investment in the open Internet.

### 3.4.4 Maximizing Social Welfare

To establish a condition when the policy maker should restrict network-neutrality regulation and allow the ISP to set up a fast-lane Internet, we have to analyze if and under which condition a fast-lane Internet increases welfare. The following theorem provides the positive effects of a fast-lane Internet on social welfare.

**Theorem 4** *Converting firms increase social welfare in terms of an increase of consumer and producer surplus and a decrease of negative externalities.*

A two-tier Internet is socially beneficial as long as these effects outweigh the fixed costs of providing the fast-lane Internet, $F$. In addition, the more firms convert based on their production decisions – mainly driven by the fixed fee the ISP charges for fast-lane Internet access – the more socially beneficial is a two-tier Internet.

The policy-maker can further mandate the ISP to invest an amount of its fast-lane Internet revenues into its open Internet. If the fixed costs of providing the fast-lane Internet are not outweighed by the positive welfare effects from converting firms, then this instrument can make a two-tier Internet socially beneficial. Otherwise, this instrument can be used to make the two-tier Internet even more socially beneficial than it would be without any investment. To enable this, we have to analyze if and under which condition such investments increase welfare. Maximizing social welfare can be written as

$$\max_I B(I) \quad \ni I \in [0, S \int_{\tilde{\theta}(S,0,I)}^{1} f(\theta) d\theta - F]. \tag{12}$$

Combining the results from our analyses of consumer surplus, producer surplus and negative externalities, the first-order condition for maximizing welfare after grouping like terms is

$$\begin{aligned}
\frac{dB(I)}{dI} &= f(\tilde{\theta})\frac{\partial\tilde{\theta}(\cdot)}{\partial I}[-\frac{\partial CS}{\partial X_c}x_c(\tilde{\theta},0)+\frac{\partial CS}{\partial X}x(\tilde{\theta},I)-S-\frac{\partial \omega}{\partial Q}q(\tilde{\theta},X(\cdot),I)] \\
&+\frac{\partial CS}{\partial X}\int_0^{\tilde{\theta}(\cdot)}\frac{\partial x(\theta,I)}{\partial I}f(\theta)d\theta+\int_0^{\tilde{\theta}(\cdot)}\frac{\partial PR(\theta,x(\theta,I))}{\partial x}\frac{\partial x(\theta,I)}{\partial I}f(\theta)d\theta \\
&-\int_0^{\tilde{\theta}(\cdot)}\frac{\partial K(\theta,X(\cdot),I)}{\partial X}\frac{\partial X(\cdot)}{\partial I}f(\theta)d\theta-\frac{\partial \omega}{\partial Q}\int_0^{\tilde{\theta}(\cdot)}\frac{\partial q(\theta,X(\cdot),I)}{\partial X}\frac{\partial X(\cdot)}{\partial I}f(\theta)d\theta \\
&-\int_0^{\tilde{\theta}(\cdot)}\frac{\partial K(\theta,X(\cdot),I)}{\partial I}f(\theta)d\theta-\frac{d\omega}{dQ}\int_0^{\tilde{\theta}(\cdot)}\frac{\partial q(\theta,X(\cdot),I)}{\partial I}f(\theta)d\theta \qquad (13)
\end{aligned}$$

subject to the constraint on investment in (12). The first-order condition in (12) contains four separate sets of effects, each on a different line on the right hand side.

The first line in (13) are the effects of an increase in investment in the open Internet that cause the indifferent firm to use the open Internet: from our ISP pricing results the usage-based fee is zero so that $x_c(\tilde{\theta},0) > x(\tilde{\theta},I)$ although the difference is small because of investment in the open Internet. As long as the effect of output on consumer surplus from the open Internet is not much greater than that from the fast-lane Internet, then these effects through output of the indifferent firm are close to offsetting. The remaining terms are the forgone fixed fee plus the additional negative externalities from the indifferent firm using the open Internet, both of which reduce welfare.

The second line in (13) are the effects of an increase in investment in the open Internet on non-converting firms producing higher levels of output, increasing consumer surplus and profit, both of which increase welfare. The third line contains the complementary negative effects on welfare of increased output from non-converting firms: higher congestion costs and greater negative externalities. These negative effects are likely to outweigh the positive effects as for an individual firm the effects on consumer surplus and profit are only due to investment increasing individual firm output. In contrast, the effects on congestion faced by individual firms are effects from the increase in aggregate output from all non-converting firms so that the last term on the second line is smaller in absolute value than the first term on the third line (see (3) and Lemma 4). The fourth line in (13) contains the direct congestion and negative externality relieving effects of additional investment in the open

Internet for non-converting firms, both of which increase welfare. As we see in our next and final theorem, these direct effects are necessary for investment to increase welfare.

**Theorem 5** *The direct effects of investment in the open Internet on congestion and on negative externalities are necessary for investment to increase welfare.*

From Theorem 5 there is only a role for a required investment in the open Internet if the impact is greater on the technology than it is on output. That is, the impact of investment in the open Internet is only welfare-enhancing if the direct effects of investment on congestion and negative externalities is more substantial than its aggregate effects on output.

# 4 Conclusions

Most prior literature examining a tiered Internet considers the Internet as a retail channel, usually based on two-sided market models. We broaden this by considering the Internet as a production input in terms of IOS and internal communication in the production process of firms.

We show that firms with higher intensity of Internet use convert to the fast-lane Internet, and the ISP chooses a fixed fee rather than usage-based pricing. Our result is consistent with a policy-maker that may wish to regulate usage-based prices. We also find that regulation allowing the ISP to set up a fast-lane Internet is beneficial as long as the positive effects on welfare – increase of aggregate output, increase of aggregate firm profits and decrease of aggregate negative externalities – outweigh the costs of a fast-lane Internet. Finally, we determine that the policy-maker mandates investment in the open Internet only if it directly reduces firm congestion costs and negative externalities. Alternatively, if the policy-maker mandates a minimum QoS from the open Internet, so long as the objective of such a policy is to maximize welfare, our analysis is identical. Thus, our analysis supports a restriction of network-neutrality regulation with the proviso that investment from ISPs may be required to maintain the viability and contributions to social welfare from the open Internet.

The following references are for the full version of the paper. The full version of the paper is available at http://www.uibk.ac.at/iwi2/tticist.

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