CHANGING THE RULES: UNIVERSAL SERVICE, QUALITY CAPS AND NET NEUTRALITY

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Abstract

Under the last considerations of network neutrality presented by United States and European Union regulation authorities, the involvement of content providers in the universal service programs is not stablished. A regulated Internet contract with a free or very small economic participation by users to access into a limited bandwidth version of the Internet service and content providers financing their participation to broadcast their high bandwidth content to increase the bandwidth could by a solution for this issue. We study a minimum quality of a service as a strategy of public policy over a broadband telecommunication services to create better absorption of technological benefits as a welfare measure for the users. As results we show a positive effect to propose universal service by quality as complement of universal service obligation, the conditions to determine the prices have to be ruled ex-ante by authorities and finally the best market scenario for welfare superior is determined by competition.

Keywords: Quality standards, Universal Service, Regulation, Net neutrality, Zero price rating.

JEL Codes: L12, L13, L15, L38, L52, L96.

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If we ask a simple question: is it possible that a broadband provider proposes a free Internet service? Suppose that it is possible, so better ask otherwise; in which context could a broadband operator propose a free Internet service as part of a Universal Service policy on broadband market?

To revisit this idea in the actual configuration of broadband services, we need to understand the importance of quality in a broadband context. Nowadays, the perception of Internet speed is considered as the single most important metric of interest in characterizing the "quality" of broadband service, *Bauer et al.* (2010). More speed perception in a *"ceteris paribus"* situation, especially over the price, will announce a better customer satisfaction. However, the different perceptions of broadband speed (capacity, advertised and achieved) difficult the analysis of data speed.

Nevertheless, speed or bandwidth does not depend only on the technical capacity of the broadband service at the present time. The high data demand from content providers (CP) has become one of the reasons why the average speed of broadband does not depend only on the Internet service provider capacity (ISP). ISPs have been turning to pricing as the ultimate congestion[1] management tool to mitigate the fear of a data saturation *Sen et al.* (2013).

Notwithstanding this situation, the financial transfers between residential ISPs and CPs would be prohibited by the zero-price rule on network neutrality, *Broos* and *Gautier* (2015). ISPs do not have the right to make CPs pay a termination fee for access to Internet consumers; the residential consumers pay uniquely to be connected to an ISP and the CPs pay to be connected to the network. This rule implies that there is a "missing price" prohibiting financial transfers between CPs and ISPs according to their explanation.

In this sense, the possibility that an ISP's differentiating charges and treatment of data will allow a better and more efficient management of the network, providing an ongoing incentive to create a more accurate service. The interaction between price and quality of service is produced when networks are under congestion. However a major source of confusion for the economic analysis comes from the different bandwidth uses of the Internet applications, *Greenstein et al.* (2016).

The presence of net neutrality address new issues to maintain the competitive balance between all actors, especially when one side of the network is not participating in the universal service funding. A new interpretation of universal service become a commitment to increase the benefits of the development of networks, as suggested in *Alleman et al.* (2009). Net neutrality and quality of service[2] introduce a new opportunity where Universal Service could be suggested as policy

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[1]One interesting work is presented in *Bourreau* (2001) , in a model of economic analysis of Internet flat rates, the author explains that Internet flat rates may create network congestion problems and one way to solve network congestion is to over-provide bandwidth. If it is too costly to do, appropriate pricing schemes might be introduced to allocate bandwidth between users in a more efficient way.

[2]A good description of this context is developed by *Altman et al.* (2011) .

over the data bandwidth.

As we note, content providers are not involved directly in the universal service obligations with a corresponding participation being taxes, funds or compensations. This legal vacuum over the content providers make a challenge in the research of a possible strategy compensation (price) as part of universal service policy to improve costumers welfare.

The lack of participation deepens much more when the demand growth for bandwidth is the current argument of technological innovations on broadband and the main economic winners are the content providers.

1 Universal service as zero price rate policy

Zero rating policy[3] could produce an externality effect over the universal service in a context of competition or vertical integration. In a competitive market some external effects could arise over the market equilibrium [4], explained in *Greenstein et al.* (2016).

However an "unlevel playing fields" as zero price rating policy could become an opportunity for universal service access. Through this policy, some services could be offered for free (e.g. free or very small priced access to a limited version of the Internet) that could support the universal service efforts to increase the access to Internet service.

We develop a normative approach of zero price rating Internet service policy as universal service strategy. Our objective is to describe the market as it should be. Our contribution is to give some public policies insights to be considered by regulation authorities.

We focus our analyze on a scenario where a regulator decides to impose a universal service as a limited version of Internet service (bandwidth limitation)[5]. This service will be financed by subsidies[6] or by a really small price from subscriber. The ISP impose data caps on use. This data caps will shape competition between content providers because the data limitation create an artificial scarcity, making users perceive different qualities of service from each content providers as explained in *Greenstein et al.* (2016). [7]

Our contribution tries to answer the question about zero pricing Internet services in the context of infrastrucutre access (free or a very small economic participation to access) to a limited version of the Internet, proposed in *Greenstein et al.* (2016). *Does expansion of use provide a benefit that merits less concern about the competitive effects or not?*

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[3]The example of "zero-rating" plans offered by local mobile operators in India to roll out Internet.org Facebook's project, and the preoccupation of government regulators about content neutrality, show the inherent tension between infrastructure access, content and net neutrality. An interesting world panorama with an analysis of zero-rating debate is exposed in *Carrillo* (2016).

[4]Selected websites or Internet services rated at zero cost to the customers, would not respect the essence of net neutrality, which requires non-discrimination between different content and applications.

[5]A rustic Internet service with a minimum of quality of service defined by the regulator. A difference as well as a complement to the existing free wifi access policies, a broadband Universal service policy, focused on bandwidth (universal minimum quality in Mb/s), looks to create better absorption of technological improvements as a welfare measure on a greater part of population.

[6]Traditional universal service financing mechanisms.

[7]A possible race for innovation in data demand and content transmission from the content providers could happen in the future. However our interest is to define if this data caps delimitation become positive for consumer access under the scenario presented before.

This paper is organized as follows. Section 2 presents an application of the concerns proposed in *Greenstein et al.* (2016), in Section 3 we start our analysis under a monopolistic ISP that provides a limited Internet service allowing a differentiated speed access to CPs that are interested to diffuse their high bandwidth content. In Section 4 we introduce the zero price rating Internet under a duopoly competition. As result we obtain a welfare superior under imperfect competition scenario. Finally, we conclude this paper.

2 The Model

Following the schema presented in *Greenstein et al.* (2016), CPs could participate with a compensation as part of universal service policy for a target population that has access to a limited Internet service and could be able to access their content with an increase of bandwidth financed by CPs [8].

Figure 1: Internet Service Providers and Content Providers rent-shifting and price structure
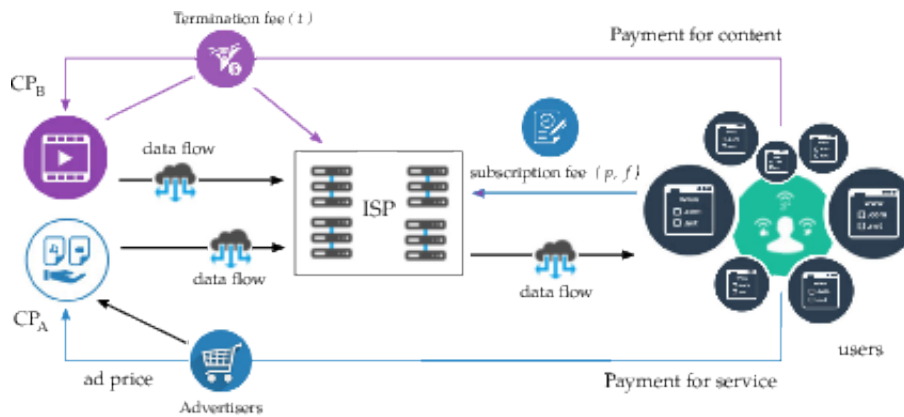
Source: Based on *Greenstein et al.*, 2016

Nowadays, universal service as zero price rule is not present in the Internet market structure. End users pay a price for a service provided by ISPs. CPs have no technical limitations to their content access and users have a unlimited content access. In this situation Internet and content access are perfect complements. Internet users' utility is defined by

$$u = f[b] - p_{isp}$$

The Internet service price p_{isp} depends on the technology deployed on the network (broadband, ultraboadband, etc). u represents the utility level of Internet users. We assume that $f[b]$ is a concave non decreasing function with decreasing marginal value as a preference function. b represents the acceded data volume[9] by Internet users. Therefore the price of Internet service depends on data speed capacities.

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[8] there are different strategies nowadays that CP employs to finance their business models as publicity or database collection.

[9] referring us to the symbol for bytes as a unit of data traffic

In the case of ISP, their benefits depend on the price charged, the number of final users α and the cost c_{isp} of providing the service. CP's profits depend on $r \cdot g[b]$ as the revenue, where r is a parameter that differs among the different CP's[10]. We assume that $g[b]$ is a non decreasing concave function. Both profits functions are given by

$$\pi_{ISP} = \left(p_{isp}[b] - c_{isp}[b] \right) \cdot \alpha \tag{1}$$

$$\pi_{cp} = r \cdot g[b] - c_{cp}[b] \tag{2}$$

3 Monopoly ISP

We assume that ISP provides a limited (bandwidth)[11] Internet service to a defined population at a price p_z which is lower than the market price p_{isp}, where $p_{isp} > p_z \geq 0$. Considering universal service from the legal definition, p_z corresponds to the net cost of providing a limited bandwidth Internet service over the network. Due to the low stream bandwidth of this network, some contents from CPs will not be able by the technical limitations, however CPs have the option to be viewed via the payment of a termination fee t (financed by themselves e.g. publicity or database collection) for access to the fast lane network bitstream[12].

As explained in *Greenstein et al.* (2016), without network neutrality ISP could give preferential treatment to their own services in fast lanes, driving out the content competitors when the ISP has a vertical integration strategy with a content provider. However the cost of a vertical integration for ISP is exogenous to Internet users at least in the first step of the strategy because zero rating price p_z under an universal service strategy is regulated and ex-ante considered. Costumer welfare is not affected and the principal objective is to increase the universal access to the Internet but the game rests between ISP and CPs.

3.1 CP optimal Traffic data

The monopolistic ISP plays the role of a gateway between CPs and Internet users to transfer data content. We define b as the acceded data from a CP by Internet users. The ISP charges a termination fee t per unit of data speed traffic to the CP that decided to propose the access to its content by a fast lane network. The CP is free to decide the kind of content or service to be acceded or displayed. The only condition to respect is the termination fee payment. Content providers chose b such that

$$b \in \arg\max_{b} \quad v_{cp}[b] = r \cdot g[b] - b \cdot t$$

$$\text{s.t.} \quad b \geq 0 \tag{3}$$

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[10]*Zhang* and *Wang* (2014) explain that revenues could result of advertisement or value-added services. The different types of CPs may produce much different revenue levels.

[11]For our research we rely on concepts and assumptions presented in *Economides* (2005); *Musacchio* and *Kim* (2009); *Economides* and *Hermalin* (2012); *Kourandi et al.* (2015); *Greenstein et al.* (2016)

[12]An interesting application of this strategy is presented by *Gharakheili et al.* (2016).

Lemma 1: *Content provider choses b such that*

$$g'[b] = \frac{t}{r}$$

Proof. See the Appendix.

Traffic data volume is limited by CP in reason of r and t. The traffic data choice of CP will depend on the relation between termination fee t and CP revenues $r \cdot g[b]$. Indeed, the possibility of a renting strategy for CPs in this scenario is crucial for their participation in the policy.

We note that under a monopolistic ISP without a specific regulation, ISP will define $t \geq r$ as a result of its market power influence. A non incentive situation for CP to participate in the market could happen.

Lemma 2: *the variation of traffic data volume for CP b affected by a variation of termination fee (t) at the optimum is given by*

$$b'_{cp}(t) = \frac{1}{r \cdot g''[b]} \tag{4}$$

Proof. See the Appendix.

3.2   ISP optimal termination fee

Fixed by regulations, zero rating price p_z corresponds to net cost of providing a limited bandwidth Internet service over the network. Without regulation on termination fee t, monopolistic ISP maximizes its profits in function of CP revenues, impacting CP termination fee. Thus, the total profits of ISP is given by

$$\max_{t} \quad \pi_{ISP} = (p_z - c_z)\,\alpha + (t)\,b^*[t]$$

$$\text{s.t.} \quad t \geq 0 \tag{5}$$

Where c_z corresponds to the cost per-subscriber. ISP determines the optimal price of t by

$$\max_{t} \quad \pi_{ISP} \quad s.t. \quad t \geq 0$$

.

Theorem 1: *with the optimal traffic data volume for CP and under universal service condition $p_z = c_z$, considered as the net cost of providing a limited bandwidth Internet service over the network, the optimal termination fee (t) charged by the monopolistic ISP to the CP :*

$$t^* = \frac{-b[t]}{b'[t]}$$

$$t^* = -b \cdot r \cdot g''[b] \tag{6}$$

The optimal termination fee for the monopolistic ISP is positive $t^* > 0$ because $g[b]$ is concave: $g''[b] < 0$. If monopolistic ISP tries to discriminate CPs, ISP will try to reduce the gap between the

optimal traffic data volume b^* and termination fee t^*, by pricing the latter at the same level as the revenue of CPs. [13]

Under these circumstances, CPs would not participate into the market. Hence, ISP determines t^* considering only the value of $b[t]$ and not the revenue level $r \cdot g(b)$ of CP.

Proof. See the Appendix.

Theorem 2 *the optimal data traffic of CPs in terms of $g[b]$ is given by substitution of (6) in lemma 1*

$$b^* = -\frac{g'[b]}{g''[b]}$$

As an intuitive result, we can state that the higher the marginal gains, the better the quality. The higher the gap between r and t, the bigger the incentive for CPs to participate. Given t^* and $b^*[t]$ conditions, termination fee is inelastic.

$$\epsilon_t = -\frac{t}{t^{*2}}$$

Proof. See the Appendix.

3.3   Universal service Internet as a substitute service

Now, we study the effect of universal service adoption as a zero rating price policy concomitantly to a normal Internet service. ISP offers both a normal Internet Service and a limited Internet service based on a zero price rate. We denote two types of contracts that users could choose, α and β corresponding to the number of users of each service. c_z and c_{isp} correspond to the cost per-subscriber of a limited Internet Service and a normal Internet Service respectively. p_z and p_{isp} corresponding to each service price of service

$$\max_t \quad \pi_{isp} = \left(p_{isp} - c_{isp}\right)\alpha + (p_z - c_z)\beta + t \cdot b[t]$$
$$\text{s.t.} \quad t \geq 0$$

Following the legal definition of universal service price, the net cost of providing the service is considered as the price of the limited Internetg, $p_z = c_z$.

Theorem 3 *under contract substitution, the optimal termination fee t is*

$$t^* = \frac{-b[t]}{b'[t]}$$

Proof. See the Appendix.

The cost of the limited Internet service (c_z) could be altered in the next steps by the monopolistic ISP as a result of a possible Internet users contract shifting. ISP could argue a loss of benefits as a result of the shifting of users. However as an *ex-ante* policy and regulated tool, the monopolistic firm cannot change the price of the limited Internet service p_z. As $p_z = c_z$, the limited Internet service

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[13] An interesting methodology to calculate the benefits of sponsored data for an individual content provider is proposed by *Andrews et al.* (2014).

net cost rests unchangeable. Only if the contract between ISP and CP is defined as a dynamic termination fee t, monopolistic ISP will re calibrate t to include the lost benefits of Internet users shifting. The CP will reevaluate their optimal data traffic just to the equilibrium.

$$\max_{t} \quad \pi_{isp} = \left(p_{isp} - c_{isp}\right)\alpha + (p_z - c_z)\left(\beta + (1 - \alpha)\right)$$

$$+ \left(1 + \frac{\left(p_{isp} - p_z\right)(1 - \alpha)}{\beta + (1 - \alpha)}\right) t \cdot b\left[t\right]$$

$$s.t. \quad t \geq 0$$

In this case, optimal termination fee t is the same as the initial situation: $t^* = \frac{-b[t]}{b'[t]}$.

Proof. See the Appendix.

Proposition 1 The termination fee t defined by ISP has to be the same no matter if it is a unique or multiple contract strategy even when there are shifting Internet users contracts, i.e. as a monopoly. ISP do not make difference in the allocation of termination fee t under different contracts. The contracts are treated separately under a price regulation p_z.

4 Duopoly

4.1 Uniformed ISP behavior

Universal service adoption as a limited Internet service based on a zero price rate in a broadband duopoly could produce a different behavior from ISPs. A first case is a uniformed situation, where both ISP operate with a Normal Internet Service and propose the limited Internet service within their contracts. This case reflects a situation where the limited service is an open regulated policy with defined specifications provided by the regulaton authorities to any ISPs. However if one of the ISPs decides not to provide this kind of contract, the second will take advantage of this situation, becoming a monopoly of the limited Internet Service.

We consider two ISPs defined as $ISP_i = 1, 2$, competing ISP set termination fees $t_i, i = 1, 2$ to maximize profits. ISPs' bandwidth are homogeneous, perfect substitutes. CPs prefer the ISP with the lowest price as long as $v_{cp}[b] \geq \min\{t_1, t_2\}$. If $v_{cp}[b] < \min\{t_1, t_2\}$, CPs do not have incentives to participate in a limited Internet service policy as the result of higher termination fees. For equal termination fees $v_{cp}[b] \geq t_1 = t_2$ CPs are indifferent to the choice between ISPs.

$$b_{cp}(t_1, t_2) \begin{cases} b_{cp}(t_1) & \text{if } t_1 < t_2 \\ \frac{1}{2}b_{cp}(t_1) & \text{if } t_1 = t_2 \\ 0 & \text{if } t_1 > t_2 \\ \\ b_{cp}(t_2) & \text{if } t_2 < t_1 \\ \frac{1}{2}b_{cp}(t_2) & \text{if } t_2 = t_1 \\ 0 & \text{if } t_2 > t_1 \end{cases}$$

Under a Bertrand's paradox, $t_1 = t_2 = c_b$. Nash equilibrium in prices is determined in termination fee $\left(t_1^*, t_2^*\right)$

Proposition 2 If ISPs adopt the same strategy over a limited Internet service policy, under a Bertrand duopoly, ISPs define termination fee t at marginal cost of data traffic. The long-run marginal cost of increasing bitstream data traffic define the price of t. Additionally, termination fee t becomes minimal due to the fact that a big cost componet of providing service is including in the net cost c_z. In a perfect competition scenario $t \approx 0$.

As in the monopoly situation, ISPs define termination fee t under substitution contracts at the same value as a unique service contract. ISPs do not make difference in the allocation of termination fee t under the presence of different contracts. The contracts are treated separately under a price regulation p_z.

4.2 Universal service Internet over an exclusivity ISP

A different situation could by presented when only one ISP provides the limited Internet service. This scenario reflects the case where the policy is targeted to only one ISP. In several cases, we see in the literature that universal service obligation is provided by the incumbent or as part of a contract specifications defined to a new player in a market. In the same case, ISP that proposes the limited Internet service take advantage of this situation in a monopoly position. In this scenario the market power of ISP is no lower than that of a monopolistic ISP, because it is the only provider of this contract. In fact, ISP may compete to obtain the exclusivity to offer the service by public bidding or paying the competitors to do not provide this service[14] as explain *Broos* and *Gautier* (2015), in the case of ISPs and Internet applications .

Exclusive ISP contracts to provide a limited Internet service induce a monopolistic behavior of ISP. The effect of Exclusivity contracts have to be evaluated over a welfare comparison.

4.3 Welfare Analysis

According to the legal definition of the universal service policy $p_z = c_z$ the price of the subscription to this Internet service will be defined as the net cost of delivering the limited Internet technology. The variation of costumers' welfare in this situation is highly positive because $p_z < p$. The total social welfare is determined by

$$SW_{monopoly}^z = r \cdot g\,[b] - c_{cp} + \Delta CW$$

Under a duopoly with a symmetric ISP behavior that provide a limited Internet service, termination fee is defined as $t_1 = t_2 = c_b$ in a Nash equilibrium in termination fee prices $\left(t_1^*, t_2^*\right)$ and according to the universal service condition $p_z = c_z$. The total social welfare is determined by

$$SW_{duopoly}^z = r \cdot g\,[b] - c_{cp} + \Delta CW$$

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[14]This kind of practices are allowed under a regulated market, at least not under the presence of a regulator.

Proposition 3 Duopoly scenario is welfare superior than monopoly scenario. Indeed $r \cdot g[b]$ is a function of t because $b = b[t]$. With the lowest pricing of termination fee, the revenue level $r \cdot g[b[t]]$ will be higher on duopoly.

$$SW^z_{monopoly} < SW^z_{duopoly}$$

Proof. See the Appendix.

Under duopoly competition, the ISPs define termination fee t above their marginal cost. Limited Internet service in duopoly has a positive impact on end users welfare. indeed following theorem 2: the higher the marginal gains, the better the quality. With a reduction of t in relation to monopolistic ISPs, CPs will allow more content financed by themselves in the limited Internet service. Users will access more content without any extra cost.

5 Conclusion

We presented a possible alternative for universal service on broadband, a kind of alternative Internet contract with a free or very small economic participation to access a limited version of the service. CP finance their participation to broadcast their high bandwidth content. We focused our analysis on a scenario where a regulator decides to impose a universal service as a limited version of the Internet service through a bandwidth limitation, financing the Internet access by subsidies or a really small price from subscriber.

The objective of this paper was to contribute to the literature with some public policies insights to be considered by regulation authorities. We have developed a very simplified model that may disregard some considerations. First, we developed a normative approach, we described the market as it should be and not as it is. Second, the vertical integration between ISPs and CPs was not included as an issue because price under a universal service strategy is regulated and *ex-ante* considered. Vertical integration becomes a dynamic evolution of data caps universal service strategy.

As mainly results we show:

- There is a positive effect to propose a Broadband universal service by quality as complement of Universal Service obligation at least in terms of access due to the reduction of subscription price to a limited bandwidth Internet service over the network.

- Limited Internet service price has to be calculated and fixed by regulations, taking into account the technical components of the service and not the possible loss of benefits or opportunity costs for Internet service providers. ISP will try to defend or justify their position in order to extract all possible benefit of this policy.

- Network neutrality policy has to be imposed to ISP in terms of termination fee t over the different CPs. Indeed, if monopolistic ISP tries to discriminate CPs, ISP will try to reduce the gap between the optimal traffic data volume pricing termination fee at the value of revenue level of CP.

- Duopoly competition scenario is welfare superior than monopoly scenario. Zero price rating Internet service in duopoly competition has a positive impact on end users' welfare.

- If this policy is to be proposed by the regulation authority, it has to be considered in a competition market structure. A reduced termination fee will be granted to CPs and more content financed by themselves will be available to end users.

In conclusion, the expansion of this policy provides benefits in terms of participation of indirect financing of universal service. Indeed, CPs are not involved in the universal service programs with a corresponding participation being taxes, funds or compensations.

Defining a limited Internet service as a policy to increase Internet penetration, the benefits merit less concern about the competitive effects, specially in regions where a large income difference between their population is present.

Appendix

Proof of Proposition 1: *optimal traffic data volume for CP, on page 6*

We consider the following payoff from content provider:

$$\underset{b}{\arg\max} \quad v_{cp}[b] = r \cdot g[b] - b \cdot t$$

$$\text{s.t.} \quad b \geq 0$$

where b is the optimization variable, v_{cp} is the utility function for content provider, in order to maximize $v_{cp}[b]$, we define a Lgagrange's function on Kuhn-Tucker conditions:

$$\mathcal{L} = r \cdot g[b] - b \cdot t - \lambda(-b)$$

The first order condition is defined by:

$$\frac{\partial \mathcal{L}}{\partial b} = r \cdot g'[b] - t + \lambda = 0 \tag{7}$$

complementary slackness Kuhn-Tucker conditions for a point to be a maximum are:

$$\lambda(-b) = 0 \tag{8}$$

$$\lambda \geq 0 \tag{9}$$

Solutions of (7) for λ are given by

$$\lambda = t - r \cdot g'[b] \tag{10a}$$

$$g'[b] = \frac{t}{r}$$

Proof of Lemma 2: *optimal traffic data volume for CP, on page 6*

If $t - r \cdot g'[b] > 0 \implies \lambda > 0$. the condition $-b = 0$ is strictly necessary to obtain $\lambda > 0$, according equation (8). In other words, the constraint is binding.

In contrast, if $t - r \cdot g'[b] \leq 0 \implies \lambda = 0$. According to equation (10a) where $\lambda = 0$, and replacing λ in equation (7), we get:

$$\underbrace{r \cdot g'[b] - t}_{h} = 0 \tag{10b}$$

Following the implicit function theorem where :

$$\frac{db}{dt} = -\frac{\frac{\partial h}{\partial t}}{\frac{\partial h}{\partial b}} \implies \frac{db}{dt} = \frac{1}{r \cdot g''[b]} \tag{11a}$$

The exact value of b in equation (11a) is $b[t]$, according to equation (10b), b depends on t at the equilibrium. However we note it only b to simplify concepts, in a strict sens the exact value is defined as:

$$\frac{db}{dt} = \frac{1}{r \cdot g''[b[t]]} = b'[t] \tag{11b}$$

From equation (11b) we can get:

$$\frac{d^2b}{dt^2} = -\frac{b'[t] \cdot g'''[b[t]]}{r \cdot g''[b[t]]^2} \tag{12}$$

Replacing (11a) in equation (12):

$$\frac{d^2b}{dt^2} = -\frac{\frac{1}{r \cdot g''[b]} \cdot g'''[b]}{r \cdot g''[b]^2} = -\frac{g'''[b]}{r^2 \cdot g''[b]^3} = b''[t] \tag{13}$$

Proof of Theorem 1: *optimal termination fee (t) monopolistic ISP, on page 6*

We now optimize the ISP program under the assumption of a concave function:

$$\pi_{ISP} = t \cdot b[t] + (p_z - c_z)\alpha \tag{14}$$

Under universal service condition p_z is defined as the net cost to provide a limited bandwidth Internet service over the network. $p_z = c_z$. Replacing in (14), we get:

$$\pi_{ISP} = t \cdot b[t]$$

$$\frac{\partial \pi_{ISP}}{\partial t} = b[t] + t \cdot b'[t] \tag{15}$$

We obtain t^* from equation (15):

$$t^* = -\frac{b\,[t]}{b'\,[t]}$$

Replacing (11a) in (15) we obtain:

$$t^* = -b \cdot r \cdot g''\,[b] \tag{16}$$

$t > 0$ because $g\,[b]$ concave $g''\,[b] < 0$.

In the same way, the second derivative of π_{isp} is simplified by (11b) and (13) .

$$\frac{d^2 \pi_{isp}}{dt^2} = \frac{1 - t'}{r \cdot g''\,[b]} - \frac{g'''\,[b]}{r^2 \cdot g''\,[b]^3} t$$

Where $g'''\,[b]$ depends on the capacity of CP to find more clients in their business model. We make the assumption $g'''\,[b] < 0$ because in the first step, CP works with a very defined clients base. CPs improve their strategies in the further steps. As result $\frac{d^2 \pi_{isp}}{dt^2} < 0$.

Proof theorem 2: *Optimal data traffic CP in terms of* $g\,[b]$ *, on page 7*

$$g'\,[b] = \frac{-b \cdot r \cdot g''\,[b]}{r}$$

$$b = -\frac{g'\,[b]}{g''\,[b]}$$

The price elasticity of CP is defined by:

$$\epsilon_t = \frac{\frac{\partial b_{cp}[t]}{b_{cp}[t]}}{\frac{\partial t}{t}} \tag{17}$$

Replacing (15) and (11b) on (17), we obtain:

$$\epsilon_t = \frac{\frac{\frac{1}{r \cdot g''[b]}}{b}}{\frac{-b \cdot r \cdot g''[b]}{t}} = \frac{\frac{1}{b \cdot r \cdot g''[b]}}{\frac{-b \cdot r \cdot g''[b]}{t}} = -\frac{t}{(b \cdot r \cdot g''\,[b])^2} = -\frac{t}{t^{*2}}$$

Proof of Theorem 3 : *optimal termination fee (t) from ISP under Zero rating price as an option to subscriber,* **on page 7**

$$\max_t \quad \pi_{isp} = \left(p_{isp} - c_{isp}\right)\alpha + (p_z - c_z)\beta + t \cdot b\,[t] \tag{18}$$

$$\text{s.t.} \quad t \geq 0$$

termination fee t is measured in function of c_z and c_{isp} corresponding respectively to the cost per-subscriber of a limited Internet service and to the normal Internet service. p_z and p_{isp} corresponding

to each service price. Under the universal service legal definition, price is measured as the net cost of provide the service, $p_z = c_z$. Simplifying 18 we obtain:

$$\pi_{isp} = \left(p_{isp} - c_{isp}\right)\alpha + t \cdot b\,[t]$$

where:

$$\frac{\partial \pi_{isp}}{\partial t} = b\,[t] + t \cdot b'\,[t] \tag{19}$$

From 19 we obtain t^*:

$$t^* = -\frac{b\,[t]}{b'\,[t]}$$

The optimal termination fee t^* does not change under the distribution of a normal Internet service.

As a second case, the optimal termination fee (t) ISP under the consideraton that monopoly benefits lost by the Internet users shifting is defined as :

$$\max_{t} \quad \pi_{isp} = \left(p_{isp} - c_{isp}\right)\alpha + (p_z - c_z)\left(\beta + (1 - \alpha)\right) \tag{20}$$

$$+ \left(1 + \frac{\left(p_{isp} - p_z\right)(1 - \alpha)}{\beta + (1 - \alpha)}\right) t \cdot b\,[t] \tag{21}$$

$$s.t. \quad t \geq 0$$

Under universal service condition p_z is defined as the net cost to provide a limited bandwidth Internet service over the network. $p_z = c_z$. Replacing in (20), we get:

$$\pi_{ISP} = \left(1 + \frac{\left(p_{isp} - p_z\right)(1 - \alpha)}{\beta + (1 - \alpha)}\right) t \cdot b\,[t]$$

$$\frac{\partial \pi_{ISP}}{\partial t} = \left(1 + \frac{\left(p_{isp} - p_z\right)(1 - \alpha)}{\beta + (1 - \alpha)}\right) b\,[t] \tag{22}$$

$$+ \left(1 + \frac{\left(p_{isp} - p_z\right)(1 - \alpha)}{\beta + (1 - \alpha)}\right) t \cdot b'\,[t] \tag{23}$$

$$\tag{24}$$

We obtain t^* from equation 22:

$$t^* = -\frac{b\,[t]}{b'\,[t]}$$

Proof of Welfare Analysis, on page 9

Under this scenario, Internet users utility is defined by:

$$u_z[b] = f[b] - p_z[b]$$

Corresponding the universal service policy with the legal definition $p_z = c_{isp}$ the price's subscription to this Internet service will defined as the net cost of delivering the limited Internet technology. Welfare superior is present in all the cases and highly positive as result of $p_z < p$. Variation of social welfare is $\Delta CW > 0$

The benefits of CPs and ISP are defined as:

$$\pi_{cp} = r \cdot g[b] - c_{cp} - (t) b^*[t]$$

$$\pi_{ISP}^z = (p_z - c_z)\beta + (t) b^*[t]$$

Under a monopolistic ISP that provides a limited Internet service, the total welfare is determined by:

$$
\begin{aligned}
Wz &= \pi_{cp} + \pi_{isp}^z \\
&= \left(r \cdot g[b] - c_{cp} - (t) b^*[t]\right) + \left((p_z - c_z)\beta + (t) b^*[t]\right) \\
&= r \cdot g[b] - c_{cp} + (p_z - c_z)\beta
\end{aligned}
\tag{25}
$$

Under universal service condition p_z is defined as the net cost to provide a limited bandwidth Internet service over the network. $p_z = c_z$.

$$Wz = r \cdot g[b] - c_{cp}$$

The total social welfare is determined by:

$$SW = W_z + \Delta CW$$

$$SW = r \cdot g[b] - c_{cp} + \Delta CW \tag{26}$$

Under a duopoly with an asymmetric ISP behavior that provides ZPR, the total welfare is determined by:

$$
\begin{aligned}
Wz &= \pi_{cp} + \pi_{isp_1}^z + \pi_{isp_2}^z \\
&= \left(r \cdot g[b] - c_{cp} - (t) b_{1,2}^*[t]\right) \\
&\quad + \left(\left(p_z^1 - c_z\right)\beta + \frac{1}{2}(t_1) b^*[t]\right) \\
&\quad + \left(\left(p_z^1 - c_z\right)\beta + \frac{1}{2}(t_2) b^*[t]\right)
\end{aligned}
$$

Under a Bertrand's paradox, $t_1 = t_2 = c_b$ a Nash equilibrium in prices is determined in termination fee $\left(t_1^*, t_2^*\right)$ and under universal service condition p_z is defined as the net cost to provide a limited

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bandwidth Internet service over the network. $p_z = c_z$.

$$Wz = r \cdot g\,[b] - c_{cp}$$

The total social welfare is determined by:

$$SW = W_z + \Delta CW$$

$$SW = r \cdot g\,[b] - c_{cp} + \Delta CW \tag{27}$$

However revenue level for CP in duopoly scenario is superior than that of monopoly scenario. Indeed $r \cdot g\,[b]$ is a function of t because $b = b\,[t]$. With a lowest price of termination fee, the revenue level $r \cdot g\,[b\,[t]]$ will be higher on duopoly.

$$SW^z_{monopoly} < SW^z_{duopoly}$$

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