Role of Digital Divide in Optimal Zero-Rating Policy

Neena Pandey, Manaswini Bhalla
IIM Bangalore
neena.pandey@iimb.ac.in, manaswinib@iimb.ac.in

Subhajyoti Bandyopadhyay
Warrington College of Business Administration
shubho.bandyopadhyay@warrington.ufl.edu

Several Internet Service Providers (ISPs) and Content Providers (CPs) have proposed zero-rating plans whereby consumers get access to certain websites without paying for it. While consumer and open-access advocates have decried these plans, arguing that they are anti-competitive and violate the principles of net neutrality, ISPs and CPs have argued that such initiatives enable segments of the world population - especially those in developing economies - to finally join the rest of the world in accessing the Internet. Extant literature on the topic has contributed to this debate by analyzing the optimality of zero-rating policy as an extension of net neutrality. In contrast, our work looks at this issue in the presence of a digital divide. We analyze the ISP's and the CPs' decision-making as well as its subsequent impact on social welfare when a fraction of the population does not have access to the Internet. Thus, the study fills the research gap of analyzing the impact that context (Internet penetration, in particular) may have on different network management strategies, under zero-rating plans. Our research finds that zero-rating plans can enhance social welfare in many cases in the presence of a digital divide. However, Internet regulators need to be vigilant, since the ISPs may sometime deviate from a strategy that maximizes social welfare. The findings have implications for policymakers arguing for their nuanced role in regulating zero-rating policies, rather than indiscriminately allowing or disallowing the practice.

Key words: zero rating, Internet service provider, Internet penetration, content provider, data subsidization, social welfare, Internet data policy

History:

1. Introduction

In December 2017, the US Federal Communications Commission (FCC) scrapped its earlier decision on net neutrality regulations that prohibited broadband providers from blocking websites or charging for high-quality service for certain content (Kang 2019). This led to an increase in speculation about the impact of this decision on the rest of the world. While some wondered if this step would encourage countries such as China to continue with its Internet restrictions, others deliberated whether, post this decision, Canada and Europe will stand firm on upholding net neutrality (Pham 2017). In India, the chairman of TRAI (Telecom Regulatory Authority of India) mentioned that their overarching goal was to keep the Indian context in mind. In a media briefing statement, he commented, "*From an Indian context, India has a huge population, huge things are going to happen on the Internet. It is important that we keep this (the Internet) open.*" (Pandey 2017). This paper builds on this sentiment and analyses the role of the extent of Internet penetration on zero-rating regulatory decisions.

Research shows that access to the Internet significantly improves the socio-economic conditions of a nation and its people. Access to the Internet increases the welfare and well-being of its users through efficiency gains and improvements in service quality towards health and education, and general empowerment (ITUReport 2017). Although the Sustainable Development Goals (SDGs) adopted by the U.N. do not mention lowering the extent of the digital divide within a population as one of its goals, the Internet and the various innovations based around it (e.g. Internet of Things, Artificial Intelligence, Cloud Computing, and Big Data Analysis) are expected to be instrumental in achieving most of these SDGs (ITUReport 2017). Therefore, increasing Internet penetration within a population remains as one of the most crucial goals for policymakers across the world.

Although a lot of progress has been made in improving connectivity, the extent of digital divide across societies is still stark (ITUReport 2017). While almost 85% of households in Europe have Internet access, that number goes down to 18% in Africa and the world average is around 48%. Figure 1 shows the Internet penetration level of different countries indicating a huge variance in

Internet penetration across the world. Given the far-reaching impact of the Internet, there is a great interest among the policymakers to bridge this gap.

[Figure 1 about here.]

Governments across the world have launched various programs to increase the Internet access among their populations. For example, India launched the Digital India plan in 2018 (GoI 2018) while the United States launched its National Broadband Plan (NBP) in 2010 (CRS 2010). Although the NBP was launched in 2010, it is still considered crucial towards the vitality of the future of the Internet (Brotman 2018). Considering the enormity of the goal of reducing the digital divide, policymakers are constantly in the lookout for ways to achieve this goal. Zero-rating plans have emerged as a potent tool to accomplish higher Internet penetration. However, such plans have brought about their share of controversies, with allegations of restricting the freedom of expression of users and the fact that the ISPs might serve the role of a "gate-keeper" for the content that finally reaches users (van Schewick 2016). In this paper, while being cognizant of such controversies, we examine the role of zero-rating plans in increasing Internet availability, welfare of consumers and the society at large.

Zero-rating plans are business offerings where consumers are offered free access to limited data on the Internet. It is defined as *the practice by service providers of offering their customers a specific set of services or applications that are free to use without a data plan, or that do not count against existing data caps* (Facebook 2015). Figure 2 illustrates the difference between a usual data-plan and a zero-rated plan, from the perspectives of all the economic agents involved. The figure differentiates between consumers who can afford to pay for the Internet (henceforth termed as Internet-endowed) and thus have access to it and the Internet-deprived consumers who cannot afford to pay for the Internet and have access to it only when zero rating is allowed. The Internet-endowed consumers pay the Internet Service Provider (ISP) for the service and thereby get access to content from content providers. In contrast, consumers who heretofore did not have access to the Internet can do so when zero-rating plans are allowed. In such an arrangement, CPs sponsor access to the Internet for all consumers by paying a fee to the ISP, which then makes the content of the sponsoring CPs available to the Internet-deprived consumers. In the following schematic, there are two rival CPs, CP1 and CP2.

[Figure 2 about here.]

The ISP benefits from the arrangement since increased data usage from consumers leads to increased revenue. Content Providers (CPs) benefit too, since, in most cases, their revenue depends on the number of visitors on their website. Zero-rated plans are beneficial to the CPs in another way: they allow these firms to tout them as part of their corporate social initiative, since it allows the hitherto underserved population to access the Internet. The free Internet can increase Internet penetration considerably in societies with large Internet-deprived populations. The Federal Communication Commission's Chairperson argued that *"[T]hese free-data plans have proven to be popular among consumers, particularly low-income Americans, and have enhanced competition in the wireless marketplace"* (Finley 2017). However, several consumer organizations question this altruistic justification and claim the zero-rating plans are just another tactic to increase their consumer base while compromising on the freedom of expression of end users (Imtiaz 2014). Accordingly, some consumer and open-access advocates have decried these plans, arguing that they are anti-competitive and that they violate the principles of net neutrality. The gate-keeping role of ISPs and CPs, where they can mutually decide on making specific content free-of-cost for consumers, has also been questioned (van Schewick 2016). Given the choice restrictions that ISPs may enforce through these plans, it has also been argued that zero-rating practices will lead to 'Minitelisation' of the Internet, i.e., shifting of the Internet from a user-centric, general-purpose network to one with a predefined purpose (Belli 2017). This may move the consumers from being active Internet users to being passive consumers of predetermined services.

Policymakers across the world have responded to these arguments in various ways. In the U.S., the FCC has decided to keep a close watch on the plans (Ebersole 2016). On the other hand, India, after opening a consultation paper to the public for their views and inputs (IndianExpress 2015), has banned such plans since February 2016 (Guha and Aulakh 2016). At the same time, various other developing countries have allowed such plans. For example, Facebook launched its zero-rated plan *Free Basics* in Zambia in July 2014, and Belarus is the latest country to allow it since April 2017. A few countries that have categorically banned such plans include Chile, Norway, Estonia, and Japan. However, in most countries with significant Internet-deprived populations, policymakers continue to explore different ways of increasing Internet penetration, most of which appear to be variants of the zero-rating plans (Yiakoumis 2015, Romanosky and Chetty 2018). In order to wade through the different arguments for and against zero-rating plans, policymakers require guidance that is grounded in thorough economic analysis, and which comes up with actionable recommendations. Our aim in this paper is to provide that analysis.

Thus far, network management issues in its various forms have been studied in various research streams such as economics (Economides and Hermalin 2012, Economides and Tåg 2012), Information Systems (Cheng et al. 2011), human rights (Carrillo 2016), and operations management (Guo and Easley 2016) among others. In the Information Systems domain, most studies on network management analyze various aspects of net neutrality (Cheng et al. 2011, Economides and Hermalin 2012). Cho et al. (2016) specifically considered the effect of zero-rating plans. However, none of these studies examine the role that context (and specifically, the context of the extent of Internet penetration within a population) can play on the impact of zero-rating plans on society. The only study that models Internet penetration level in network management (Guo et al. 2012) examines how net neutrality regulation can impact Internet penetration level in society. In contrast, the current study examines the how the level of Internet penetration can affect the optimal choices of the ISP and CPs that offer zero-rating plans.

Considering that the most persuasive argument against zero-rating plans is the gate-keeping role that ISPs may play once these plans are allowed (van Schewick 2016), this research effort examines the differential incentives that ISP may have in acting as the Internet gatekeeper under various broadband coverage scenarios. We study how ISP's choice changes with contextual parameters like the extent of the digital divide in society. In fact, we believe that our research is the first one to examine the combined effect of ISP strategy, competition among CPs and the level of the digital divide in society. Using a game-theoretic framework, we compare consumer surplus and social welfare when the ISP chooses to zero rate against the baseline scenario of it choosing not to do so.

Our research finds that in geographies with very high or very low levels of Internet penetration, the ISP's optimal choice is to not offer zero rating to either content provider. However, in geographies with intermediate levels of Internet penetration, the ISP will choose to offer zero rating to either one or both the CPs. This choice depends upon the relative competitiveness of the CPs involved. Social welfare analysis shows that in geographies with Internet penetration above a threshold level, the ISP's choice of not offering zero rating to any CP could be sub-optimal. Generally, the optimality or sub-optimality of the ISP's decisions in geographies with intermediate levels of Internet penetration depends upon the relative competitiveness of the CPs. Thus, our research findings argue for a more nuanced decision making for regulators on zero-rating plans. Rather than deciding whether to summarily allow zero-rating plans or not, it should suffice for the regulators to restrict the sub-optimal choices made by the ISP. The regulators can enhance social welfare by monitoring the choices made by the ISP rather than completely banning the zero-rating plans which are welfare-enhancing in many cases.

In the following section we discuss the latest academic conversation on the topic. This is followed by the details of the stylized model that we employ to analyze the impact of zero-rating plans and the results of that analysis. We then discuss propositions of interest and the contribution of our research to devise suitable guidelines for policymakers as they contemplate the regulation of zero-rating plans.

2. Literature Review

Internet governance is an issue that interests both academicians and practitioners alike. The interest is fueled by ever-increasing social, economic and political activities on the Internet and the wide range of issues, with managerial and regulatory significance, emanating out of those transactions. The ever-burgeoning literature spans across several research streams, including economics, operations management, information systems, public policy, human rights studies, international law, and cyberlaw. This reflects the inter-disciplinary nature of issues covered under the domain of Internet governance, and network management is one such issue.

One of the popular topics that researchers have investigated under network management is the issue of net neutrality, especially in the area of economics-driven IS research (Economides and Hermalin 2012, Guo et al. 2012). Most of the studies discussing subsidization or prioritization of data by CPs are driven by the issue of network congestion and hence are seen as a way to compensate the ISP for their investments in the Internet infrastructure (Ma 2014, Economides and Hermalin 2012). THe different aspects analyzed under this stream of research includes the link between net neutrality and various issues of interest like content innovation (Guo and Easley 2016), broadband market coverage and innovation (Guo et al. 2012), and incentives for network infrastructure investment (Gupta et al. 2011) and others.

Although zero-rating plans do not involve paid prioritization of CP's data, the debate on whether these plans violate net neutrality is still an open question. Various open-access advocates and civil society organizations (CSOs) argue for zero-rating plans being a violation of the principles of net neutrality and as a result, its analysis as a special case of net neutrality (Finley 2017). Consequently, the literature on zero-rating plans is relatively scant. Not many studies examining network management issues consider this phenomenon of zero rating where, although the CP subsidizes its content for the end consumers, there is no discrimination between the speed of delivery of the sponsored data and that of the non-sponsored data.

There are two broad categories of zero-rating plans: ISP-initiated plans and sponsored-data plans. In the first, Internet Service Providers offer free data to their subscribers with no revenue-sharing agreement between the ISPs and the Content Providers (CPs). In this case, the ISPs consider such offerings as providing differentiated service to their customers, for e.g. Wikipedia Zero being offered free-of-cost on various platforms around the world[1] (Reilly 2018). The sponsored data plans, on the other hand, are more common and involve agreements between the CPs and ISPs such that the data used by the subscribers from a particular CP is paid for by that CP to the extent that the CP is willing to do so (Eisenach 2016). Since this paper deals with the second type of zero-rating plans, we review the literature covering these plans.

Cho et al. (2016) develop a game-theoretical model to examine zero-rating plans to analyze the effect of sponsorship of consumer usage data. They examine the dependence of the ISP's network management choice on revenue rates of the CPs and fit cost (i.e., the disutility cost incurred from the difference between the consumer's preferred and consumed content) of customers. They also identify conditions under which these choices deviate from social optimum. Another interesting study (Ma 2014) analyzes a special type of sponsored data-plan termed as 'time-dependent sponsored data-plan' in which strategic users, who have patience to use data at different time slots of the day, can have different impact on bandwidth utilization, CPs profit, and users welfare. Such plans are found to benefit all the parties involved, and proponents have therefore argued that they should be allowed by the regulators (Zhang et al. 2016). Another study by Pang et al. (2017) shows how deregulation of subsidization could increase an ISP's utilization and revenue, strengthening its investment incentives. The research also finds that subsidization competition will increase the competitiveness of the Internet content market, but at the same time cautions regulators to regulate access prices by the ISP if the ISP market is not competitive enough. A few researchers introduce the concept of edge caching (caching video content on edge networks in advance and deliver the cached contents to local video users directly, without involving data cost for users) will impact the CP's data sponsoring strategy as well as users' behavior and the market for data. Most of the work under content subsidization strategy concerns finding variations of zero-rating plans; however, all these studies assume that the Internet market is fully covered.

Another stream of research caters to the freedom of expression debate taking place around the zero-rating plans and views it through a human rights perspective. The findings examines the role

[1] The Wikimedia Foundation plans to end this offering in developing countries soon.

of context in understanding the impact of such regulations (Carrillo 2016). Acknowledging that supporters of such plans offer these as exceptions made to the right to “freedom of expression” towards achieving a legitimate aim of acceptable necessity and proportionality, the paper argues that whether an aim is legitimate or not depends upon the country’s social, economic and political conditions. It advises a constructive contextual analysis to better understand the implications of regulations such as these.

In the backdrop of above literature, we place our work at the intersection of three prominent studies that we have mentioned earlier: (1) Cho et al. (2016)’s game-theoretic analysis of zero-rating, (2) Carrillo (2016)’s argument favoring context-based study and (3) Guo et al. (2012)’s stress on Internet penetration being an important contextual parameter in analyzing network management regulations.

Cho et al. (2016) develop a game-theoretical model examining zero-rating plans to analyse the effect of sponsorship of consumer data usage. The study analyzes this impact in a social and economic context assuming complete market coverage. In the current research work, we relax this assumption and analyse the launch of zero-rating plans in societies with significant digital divide. Guo et al. (2012) examine the impact of net neutrality regulations (allowing prioritized content for a certain fee) on broadband coverage for the end consumers, with the explicit assumption that the market is not fully covered.

Our paper differs from the prior literature in three ways. First, we specifically analyze zero-rating regulations, i.e. no data prioritization is involved. Second, while the prior literature acknowledges different levels of Internet penetration in different societies and studies the impact that these regulations can have on broadband Internet penetration, we model Internet penetration to examine how different levels of internet penetration within a population impact the decisions of the ISP, the CPs and the consumers. We also study the impact of the level of Internet penetration on social welfare as a result of these regulations. Third, owing to it being an extremely complex model, the results obtained in Guo et al’s study are largely numerical. In the current study, we are able to derive strong analytical results and are therefore able to make more generalized claims.

3. Model

In this model, we consider a two-sided market framework consisting of a single Internet Service Provider (ISP) that provides an Internet platform for consumers and Content Providers (CP)s to engage in creation and delivery of digital content. On one side there are two CPs that use the platform to provide content to consumers and on the other side are consumers who use the platform for accessing content.

3.1. Internet Service Provider (ISP)

We assume a single ISP that provides a platform for CPs and consumers to offer and access content respectively. Under zero-rating plans, agreement between the ISP and the CPs allows consumers to have free access to limited data on the Internet. At the beginning of the game, the ISP decides on its network management options. The ISP can offer zero-rating plans to one or both CPs or offer plan to none. We denote the two CPs as CP L and CP H and use indicator functions I_L and I_H to indicate whether ISP offers them zero rating, respectively. The ISP also simultaneously decides corresponding per-unit data access price 'p' that CPs will have to pay to the ISP to subsidize content for consumers. This optimal price 'p' may differ for each network management option chosen.

Table 1 lists the network management choices that the ISP can exercise and Table 2 provides the list of notations referred to in the model.

[Table 1 about here.]

[Table 2 about here.]

3.2. Content Providers (CPs)

We assume that competing CPs provide horizontally differentiated content. This horizontal aspect of content could be the level of advertisement, or political alignment of the content etc. We represent this aspect of content preference as a continuous variable represented by a line [0,1]. We assume that the CPs in the model are at the two extreme ends of this spectrum, CP L at 0 and CP H at 1.

As is common in the extant literature, we assume that the two CPs garner their revenues mainly from advertisers who advertise on their site. In other words, the CPs provide their content free of cost to consumers while getting their revenue from advertisers that target the consumers who visit the websites for the content. In the industry, this is referred to as the Average Ad Revenue per User or AARPU (eMarketer 2018). Thus, each CP's goal is to get as many consumers to visit their websites as possible. As the reference indicates, different CPs exhibit marked differences in their AARPUs. Consequently, we assume that the two CPs differ in their revenue-generating capabilities. Without loss of generality, we assume CP H (the dominant CP) has an ability to generate higher revenue per packet consumed as compared to CP L. We denote the relative revenue generating capability of the two CPs as a ratio of their independent revenue generating capabilities, i.e. $M = r_L/r_H$, where r_L and r_H are the revenue generating capabilities of CP L and CP H respectively. Since $r_L \leq r_H$, M is always between 0 and 1.

When ISP offers zero-rating plan to CPs, each CP chooses the amount of content to subsidize, λ_{si}, $i \in$ {L, H} to its consumers. The CPs use amount of content subsidized as an instrument to compete with each other.[2] When a CP chooses to subsidize λ_{si} content, it must do so for all its consumers irrespective of whether they are Internet-endowed or Internet-deprived: it is not possible for CPs to selectively subsidize its content only to one section of the population.

3.3. Consumers

We assume that there is a unit mass of consumers who derive positive utility from accessing content on the Internet. In this model, we also assume that there is incomplete Internet penetration in the society at the beginning of the game. To begin with, β proportion of population has access to the Internet and is referred to as Internet-endowed whereas $(1-\beta)$ proportion does not have access to Internet at the beginning of the game - in other words, they are the Internet-deprived consumers. In the text that follows, we sometimes refer to these two classes of consumers as the β and the $(1-\beta)$ consumers respectively.

[2] When the ISP does not offer zero-rating plan to any CP, CPs do not get to choose anything

We assume that each consumer in both sets of population (Internet-endowed and Internet-deprived) is characterized by an ideal level of horizontally differentiated content. Each consumer in the Internet endowed (or deprived) segment of the society is represented by x^{β} ($x^{1-\beta}$) respectively. We assume x^{β} ($x^{1-\beta}$) to be uniformly distributed over [0,1].

Though the β consumers have access to Internet at the beginning of the game, they still have to pay to consume it. We assume that each β consumer has a constant demand for Internet content, λ. For every network management option that the ISP can choose, β consumers must decide which CP to consume their content from. If the consumer chooses to consume from a CP that zero-rates its content, then the consumer pays data access price to the ISP only for the amount of data that is not subsidized by the CP. For example, suppose the consumer chooses content from CP H that subsidizes $\lambda_{s,H}$ units of data to its consumers. In this case, Internet-endowed consumer gets $\lambda_{s,H}$ units of data free from CP H but buys the remaining (λ - $\lambda_{s,H}$) units of data from ISP. However, when β consumer consumes content from a CP that does not zero-rate, then it purchases all of its data requirement, λ, from the ISP.

Internet-deprived (1-β) consumers do not have access to the Internet at the beginning of the game. They access data only when at least one of the CPs subsidizes it for them under a zero-rating plan. Thus, demand for Internet data is not constant from the $(1-\beta)$ consumers and it depends upon the amount of content zero rated by the CPs. When only one CP, say CP H, offers zero-rated data, all of (1-β) consumers consume content, $\lambda_{s,H}$ from CP H only. When both CPs offer zero rating, Internet-deprived consumers consume content from either one of the CPs.

3.4. Timeline of the model

We now discuss the model timeline. First, the monopolist ISP decides on its network management option. The ISP can offer zero-rating plans to one, both or neither of the CPs. Subsequent to this decision, the ISP also decides on the per-packet data access price p that it will charge. Following Cho et al. (2016) and Economides and Hermalin (2012), we assume that there are no data caps and the data is charged on a per-packet basis. Next, conditional on being offered the option to zero-rate, CPs decide on how much data to subsidize to consumers $(\lambda_{s,L}, \lambda_{s,H})$. Once the CPs decide on the amount of data to be subsidized, consumers choose which CP to consume their content from. In cases when the ISP offers a zero-rating plan to only one CP, we assume that all Internet-deprived consumers consume content from that CP only. Figure 3 shows the timeline of the model.

[Figure 3 about here.]

3.5. Players' Pay-offs

In this section, we discuss the pay-offs of the players in the game.

ISP's Profit

The ISP's profit is a function of data access price, p, and the expected demand for data, both from Internet-endowed and Internet-deprived consumers. It is expressed as follows:

$$\pi_{ISP} = p\lambda(D_L^{\beta} + D_H^{\beta}) + p * (I_L \lambda_{s,L} D_L^{1-\beta} + I_H \lambda_{s,H} D_H^{1-\beta})$$

In the above expression, the first term is the revenue generated by ISP from the Internet-endowed (β) consumers. For each such consumer, ISP receives p per unit of Internet data consumed. ISP receives this amount directly from the consumer when it does not offer a zero-rating plan to any CP. Alternatively, it receives part of this amount from the CPs and the consumers directly. D_L^{β} and D_H^{β} are fractions of β consumers who consume content from CP L and CP H respectively. Thus, $D_L^{\beta} + D_H^{\beta} = \beta$. The second term of the profit expression is the revenue generated from $(1-\beta)$ consumers. Demand from these consumers is realized only when the ISP offers zero-rating plan to at least one of the CPs and that CP subsidizes a non-zero amount of data for consumers, i.e. when $\lambda_{s,L}$ or $\lambda_{s,H}$ are not zero. $D_L^{1-\beta}$ and $D_H^{1-\beta}$ are fractions of $(1-\beta)$ consumers who consume content from CP L and H respectively (i.e. $D_L^{1-\beta} + D_H^{1-\beta} = 1-\beta$), which is conditional on the fact that at least one of the CPs offers zero-rated content. The marginal cost of the ISP is normalized to zero.

Content Provider's Profit

A CPs' profit is a function of the expected demand for data from the β and the $(1-\beta)$ consumers, the amount of data that they are willing to zero rate ($\lambda_{s,L}$, $\lambda_{S,H}$), their per-packet revenue generating capability (r_L, r_H), and data access price, p. The CPs' profit equation can be written as follows:

$$\pi_i = (r_i\lambda - I_i * p\lambda_{s,i})D_i^\beta + I_i * (r_i - p)\lambda_{s,i}D_i^{1-\beta},\ \forall i \in \{L, H\}$$

In the above profit expression for π_i, the first term represents the revenue generated from Internet-endowed consumers who choose to consume content from CP i. From each of these consumers, CP i receives revenue $r_i\lambda$ irrespective of whether it zero-rates content or not, where r_i is the per-packet revenue-generating capability of CP i. If CP i offers a zero-rating plan, it subsidizes $\lambda_{s,i}$ packets of Internet data for the Internet-endowed consumers. Therefore, it pays $p * \lambda_{s,i}$ per β consumer that consumes from CP i, to the ISP. The second term in the profit expression is the revenue generated from Internet-deprived consumers, when CP i is allowed to zero rate data. In this case, it generates revenue r_i and pays price p per unit of data that it subsidizes, $\lambda_{s,i}$, per $(1-\beta)$ consumer.

Consumer's Utility

We model the utility of consumers for Internet based on Cho et al. (2016)'s consumer Internet utility model. Consumers derive utility from the Internet in three parts: gross value function (gross valuation of the content, $V^\beta(\lambda)$), disutility cost incurred from the difference between consumer's preferred and consumed content and the cost of Internet data access that consumers pay the ISP. Thus, the utility of a β consumer when he consumes content from CP L or CP H are given by the following expressions (respectively):

$$U_L^\beta(x) = V^\beta(\lambda) - xt - p(\lambda - I_L * \lambda_{s,L})$$

$$U_H^\beta(x) = V^\beta(\lambda) - (1-x)t - p(\lambda - I_H * \lambda_{s,H})$$

In the above expressions, $V^\beta(\lambda)$ can take any functional form. We assume that 't' is the per unit fit cost of deviation that a consumer incurs in moving away from their ideal content, and is borrowed from the Hotelling framework (Hotelling 1929). The third term is the data access cost. In cases when the CPs are offered zero-rating plans, this cost is reduced by the amount of data units that CPs subsidize.

Since Internet-deprived consumers access content only when the ISP offers zero-rating plan to the CPs, they do not incur any data access cost. Thus, utility of a $(1-\beta)$ consumer is expressed as follows:

$$U_L^{(1-\beta)}(x) = V^{(1-\beta)}(\lambda_{s,L}) - xt$$

$$U_H^{(1-\beta)}(x) = V^{(1-\beta)}(\lambda_{s,H}) - (1-x)t$$

The first term in above expressions represents gross valuation of the content. This function is assumed to be constant. Thus, when both CPs are offered zero-rating plan, both CPs get to equally divide the Internet-deprived consumers' market among themselves. The second term is the fit cost of consumer which she incurs in moving away from its ideal content.

4. RESULTS & ANALYSIS

We solve for the subgame perfect Nash equilibria in this game. We first solve the consumers' problem of choosing which content provider to choose content from. Both β and the $(1-\beta)$ consumers observe the amount of data subsidized by CPs and the per unit data access price. When the ISP does not offer a zero-rating plan to any CP or CPs do not subsidize data, then only the β consumers purchase λ packets of Internet content from ISP at a per-unit price decided by the ISP.

The marginal consumer who is indifferent between consuming content from CP L and CP H, among both β and the $(1-\beta)$ consumers is denoted by $\bar{x}^{\beta}$ and $\bar{x}^{(1-\beta)}$ respectively. We derive the expression for this marginal consumer by equating its utility from CP L and CP H, i.e. the condition that the consumer is indifferent between choosing content from CP L or CP H. This marginal consumer depends upon the ISP's network management decision of offering zero-rating plan to the CPs, the data access price charged, p and the amount of data the CPs subsidize. Table 3 indicates the marginal consumer for each of ISP's choices for both the Internet-endowed and Internet-deprived consumers.

[Table 3 about here.]

We now solve for the amount of data that the CPs zero rate, $\lambda_{s,i}$. This amount depends upon the ISP's network management decision and the data access price that the ISP charges based on that decision.

We lay out CP i's problem to choose $\lambda_{s,i}$ as:

$$Max_{\lambda_{s,i}}\ \pi_i = (r_i\lambda - I_i * p\lambda_{s,i})D_i^{\beta} + I_i * (r_i - p)\lambda_{s,i}D_i^{1-\beta},\ \forall i \in \{L, H\}$$

subject to:

$$0 \leq \bar{x}^{\beta},\ \bar{x}^{(1-\beta)} \leq 1 \tag{1}$$

$$0 \leq \lambda_{s,i} \leq \lambda \tag{2}$$

$$U_i^{\beta}(x) \geq 0, \forall x \leq \bar{x}^{\beta} \ \text{ when i=L, } \forall x \geq \bar{x}^{\beta} \ \text{ when i=H} \tag{3}$$

$$U_i^{1-\beta}(x) \geq 0, \forall x \leq \bar{x}^{1-\beta} \ \text{ when i=L, } \forall x \geq \bar{x}^{1-\beta} \ \text{ when i=H} \tag{4}$$

Here, constraint (1) indicates that the marginal consumer is within the range assumed. Constraint (2) indicates that the CPs subsidize at most the entire content consumed by a consumer. Constraints (3) and (4) specify the participation constraints of the marginal consumer.

Finally, we solve for the ISP's problem, where it decides which CP to choose for zero rating and data access price per packet p. We lay out the ISP's problem to choose the price per packet, p given its network management options as:

$$Max_p\ \pi_{ISP} = p\lambda(D_L^{\beta} + D_H^{\beta}) + p * (I_L\lambda_{s,L}D_L^{1-\beta} + I_H\lambda_{s,H}D_H^{1-\beta}),$$

Along with the above mentioned constraints (1-4), ISP's profit maximization problem has an additional constraint (5) to ensure participation of CPs, as follows:

$$\pi_L(\lambda_{s,L}) \geq 0,\ \pi_H(\lambda_{s,H}) \geq 0 \tag{5}$$

We now discuss the major findings of our analysis. The following Lemma describes the optimal data access price charged by ISP.

Lemma A: *When the ISP offers zero rating to either one or both CPs, then data-access price p charged by the ISP is inversely proportional to the proportion of Internet-endowed population, β, i.e. $p \propto \frac{1}{\beta}$. On the other hand, when zero rating is not offered, the data access price is independent of β.*

Proof: See Appendix 1.1

The ISP's revenue is directly proportional to the expected demand from both β and the $(1-\beta)$ consumers. While the data demand from the first set of consumers, $(\beta * \lambda)$, is inelastic with respect to price, the data demand from Internet-deprived consumers is extremely elastic. $(1-\beta)$ consumers consume only the amount of data zero-rated by the CPs $(\lambda_{s,L}, \lambda_{s,H})$, which is inversely proportional to the data-access price p charged by the ISP. This is because higher the data-access price, lower is the amount zero rated by the CPs. Moreover, when a CP zero-rates its content, it subsidizes data for both the β and the $(1-\beta)$ consumers. Thus, it bears the subsidization cost for both types of consumers, but its revenue from its β consumers remains unchanged. Thus, in a geography where Internet penetration is high i.e. with a high β, the CPs' incentive to zero-rate decreases. This is because for a unit increase in expected revenue from Internet-deprived consumers, the CPs will have to bear the cost of zero-rating the entire population. Thus, in such a geography, to incentivize the CPs to zero rate, the ISP will have to charge a price lower than in a geography where Internet penetration is lower. The higher the Internet penetration, the lower is the data access price that the ISP will charge to incentivize the CPs to zero rate.

When the ISP does not offer zero rating to any CP, it fixes a data access price just enough to keep the Internet-endowed consumers incentivized to consume the Internet content. Since the utility of the β consumers is independent of the level of Internet penetration, data access price in this case is independent of β. Table 4 indicates optimal price that the ISP sets under the four network management options that it can choose from. These prices are derived from profit maximization problem of the ISP for each of the options.

[Table 4 about here.]

Comparing the pricing strategy of ISP for its different network management option indicates that in geographies below a certain level of Internet penetration, the ISP's optimal price when it allows zero rating is higher than when it does not allow zero rating. In contrast, for geographies above that level of Internet penetration, the converse is true, i.e. the ISP's optimal data access price when it allows zero rating will be lower than when it does not allow zero rating.

Lemma B: *When the ISP offers zero-rating plans to either one or both CPs, its optimal data-access price is highest when it offers the zero-rating plan only to the dominant CP.*

Proof: See Table 4

The ISP's revenue depends upon the data access price and the demand for data. The data demand from β consumers, λ, is inelastic. However, the data demand from $(1-\beta)$ consumers is highly elastic. This demand is same as the amount of data that the CPs are willing to zero-rate, which depends upon their revenue-generating capability and data-access price. When the ISP offers zero-rating plan to only the dominant CP, given its higher revenue-generating capability, the ISP can charge a higher price, which is just low enough to incentivize the dominant CP to zero-rate. In the case when ISP offers zero-rating plan to the less dominant CP or to both the CPs, the ISP will have to lower the price to incentivize the less dominant CP to zero-rate. However, when the ISP offers zero-rating plans to both CPs, competition between the two CPs to acquire a larger market share allows the ISP to charge higher price than when only the less-dominant CP is offered to zero-rate. The higher the relative revenue-generating capability of the two CPs, the higher is the data-access price that the ISP can charge.

4.1. *ISP's Network Management Options*

In this section we discuss the optimal network management decisions of the ISP.

Proposition 1: The choice of the ISP regarding which CP to offer zero-rating plan depends upon two parameters: (i) the degree of Internet penetration, β, and (ii) the relative revenue-generation capability of the two competing CPs, M.

- For very high and very low levels of Internet penetration, the ISP does not offer zero-rating plan to any CP, whereas for intermediate values of β, it offers zero-rating plans to either one or both the CPs.

- The choice between whether to offer zero-rating plan to one or both CPs depends upon the relative revenue-generating capability of the two CPs, M. For M less than a threshold M^*, the ISP offers zero-rating to only the dominant CP whereas for higher value of M, the ISP offers zero-rating plan to both the CPs [3].

Figure 4 presents these findings in a graphical format. Refer to Appendix 1.4 for detailed derivation of different threshold values.

[Figure 4 about here.]

High levels of Internet Penetration, $\beta \geq \beta_2$

In geographies with substantially high Internet penetration β, to incentivize the CPs to zero rate, the ISP has to charge a relatively low data-access price (Lemma A). Allowing zero-rating implies charging a low price that will lead to an increase in data traffic from a relatively small base of Internet-deprived consumers but at the cost of lower net revenue from Internet-endowed consumers (because of lower data-access price). For substantially high β, the increase in traffic from the relatively small number of Internet-deprived consumers is not high enough to compensate for the decrease in revenue from Internet-endowed consumers. Thus, it is not beneficial for the ISP to offer zero-rating plans in such populations.

Low levels of Internet Penetration, $\beta \leq \beta_1$

In markets with very low level of Internet penetration, the optimal data price that the ISP charges when it offers zero-rating is much higher than when it does not offer zero-rating (Lemma

[3] The ISP never has the incentive to offer only CP L to zero rate

A). At such high prices, the CPs do not have any incentive to zero-rate as the data-access price per packet is more than the CPs' revenue-generating capability. Moreover, becuase of the high price charged to make zero-rating possible, the utility of the Internet-endowed consumers is negative, dissuading them from accessing Internet. Thus, at very low levels of Internet penetration, the ISP will choose to not offer zero-rating to either CP.

Intermediate levels of Internet Penetration, $\beta_1 \leq \beta \leq \beta_2$

In geographies with intermediate levels of Internet penetration, the optimal price at which the ISP offers zero-rating to the CPs may be higher or lower than the data-access price when no zero-rating is offered to any CP. Whether the zero-rated price is higher or lower than non-zero-rated price depends upon the level of Internet penetration in the population. In either case, the ISP has an incentive to offer zero-rating plans.

When the zero-rating price is higher than the non-zero-rating price, the ISP benefits both from the higher price as well as additional data traffic generated because of the zero-rating, which incentivizes the ISP to zero-rate. In contrast, when the ISP's optimal data-access price in the zero-rating case is lower than non-zero rating case, the loss of revenue because of the lower price is compensated by the much higher data traffic owing to the higher amount of data being subsidized. Therefore, in geographies with intermediate levels of Internet penetration, the ISP always has the incentive to offer zero-rating.

Choice between the dominant CP or both CPs

The amount of data that a CP zero-rates depends upon its revenue-generating capability. In the case when the ISP offers zero-rating to both CPs, the amount also crucially depends upon the data zero-rated by the other CP. Here, the amount of data zero-rated by one CP is directly proportional to the amount zero-rated by the other CP. A low M implies that the revenue-generating capability of one CP (CP L) is much lower than that of other CP (CP H). For a low M, CP L zero-rates much lesser data than CP H. In this case, if the ISP chooses both CPs to zero-rate, because of the interdependence in the amount of data zero-rated by the two CPs, the total amount zero-rated by two CPs will not be as high as the amount zero-rated by CP H if only CP H is offered zero-rating. This happens because when only CP H is offered zero-rating, the amount of data that it zero-rates is not constrained by CP L's zero-rated data amount.

A high M implies that the revenue generating capabilities of the two CPs are comparable. In this case, if both CPs are offered zero-rating plans, competition among them leads to much higher zero-rated content. Although the data-access price charged by the ISP when both the CPs are offered zero-rating plans is lesser than the price when only the dominant CP zero-rates, the increased amount of zero-rated data by the two CPs compensates for the lower data-access price.

4.2. *Welfare Analysis*

In this section we analyze how the ISP's network management decisions fare in terms of the welfare that they generate, both for consumers as well as for the society as a whole. Combining these results with the ISP's network management decisions for different combinations of societal (Internet penetration level, β) and market (relative revenue generating capability of the CPs, M) conditions, we discuss the policymaker's need for intervention.

The analysis provides recommendations to policymakers towards achieving their goals. Depending upon the varied goals that policymakers may have, they may need to intervene differently under different scenarios. In geographies with very low levels of Internet penetration, regulators or the policymakers may focus only on increasing Internet penetration. Therefore, their market intervention strategy may solely depend upon the consumer surplus of Internet-deprived population. In other situations, they may care to enhance the total consumer surplus or the entire social welfare(i.e., the joint surplus of all consumers and the producers (ISP and CPs) taken together). Thus, we discuss a policymaker's need for intervention in different scenarios depending upon their goals and the impact of ISP's decision in that context. We also find conditions under which the policymaker, depending upon its objective, should intervene. Our results argue for nuanced role of regulators that should vary under different market (M) and societal (β) conditions.

4.2.1. Consumer Surplus Analysis

The following two propositions discuss the optimal choice of the policymaker when their objectives are increasing Internet penetration and total consumer surplus. By total consumer surplus, we imply combined consumer surplus of the β as well as the $(1-\beta)$ population.

Proposition 2: *Internet penetration is higher when ISP offers zero-rating plans than when it does not. This holds for all values of* β *and* M*.*

When the ISP does not offer zero-rating plan to any CP, Internet-deprived consumers can never gain Internet access. Thus, the Internet penetration is least in this case. In every other network management decision of the ISP, the ISP offers zero-rating plan to at least one of the CPs. In each of these cases, the Internet-deprived population gains Internet access, sometimes selectively and at other times from either CP. When the ISP offers zero-rating plan to only one CP (CP L or CP H), the Internet-deprived population accesses data only from that CP. When ISP offers zero-rating plan to both CPs, along with access to the Internet data, the Internet-deprived population will also have choice of the CP from whom to consume data. Given this choice of CP to consume the data from, the consumer surplus of Internet-deprived consumers will be highest when ISP offers zero-rating plan to both the CPs.

To provide an intervention strategy to policymakers whose objective is to increase Internet penetration, we combine this result with Proposition 1 which illustrates ISP's optimal choices for different combinations of β and M. To maximize Internet connectivity among the hitherto Internet-deprived population, the ISP's decision of not allowing zero rating is sub-optimal in all geographies for any level of M. Moreover, if the policymaker also intends to provide *choice* to the Internet-deprived population, in terms of CPs from whom to consume data, it should intervene in any network management decision of ISP that does not offer zero-rating plan to both CPs.

Figure 5 illustrates the areas (shaded) in β-M plane where policymaker needs to intervene and ensure zero-rating plan offering to both CPs.

[Figure 5 about here.]

Proposition 3: *Above a threshold level of Internet penetration, $\beta^*(M)$, total consumer surplus when the ISP offers zero-rating plan to both CPs is higher than when it does not offer zero-rating plan to any CP. This threshold level of Internet penetration varies with the relative revenue generating capability of the two CPs.*

In geographies with low Internet penetration ($\beta < \beta^*(M)$), the optimal price at which ISP offers zero-rating plan to CPs is very high. At this price, the utility of Internet-endowed customers from consuming Internet is zero because of high payout for data access. This disincentivizes their usage of paid Internet. At such high data access price, CPs also do not have incentive to zero-rate, leaving Internet-deprived consumers without any data access. Thus, the surplus of both Internet-endowed and Internet-deprived consumers is less when data is zero-rated than when no zero-rating plan is offered.

In geographies with high Internet penetration ($\beta \geq \beta^*(M)$), the optimal price at which ISP offers zero-rating plan to the CPs is low. This low price impacts the consumer surplus in two ways. First, it incentivizes the CPs to zero-rate more data, which increases the surplus of both the Internet-endowed and Internet-deprived consumers because of higher amount of subsidized data. Second, the lower price also increases the utility of Internet-endowed consumers further by reducing their outlay towards paid data access. Therefore, when β is high, consumer surplus is higher when both CPs are allowed to zero-rate than when no zero rating is allowed.

Again, to provide an intervention strategy to policymakers when their goal is to enhance total consumer surplus, we combine this result with the ISP's decisions as mentioned in Proposition 1. We present two conclusions on the suboptimal decisions made by the ISP. The ISP makes suboptimal decisions under two scenarios: (i) if the ISP allows both CPs to zero rate in geographies with Internet penetration below β^*, and (ii) if the ISP does not allow any CP to zero rate in geographies with Internet penetration above β^*. The shaded area in Figure 6 illustrates the areas in β-M plane where the policymaker should intervene if it wants to maximize consumer surplus.

[Figure 6 about here.]

In the figure, Region I indicates those combinations of β and M values where ISP makes a non-optimal decision to offer zero-rating plan to both CPs. Since not offering zero-rating plan to any CP for those value of β and M leads to higher consumer surplus, the policymaker should intervene when β is low and M is high by not allowing zero-rating plans. Regions II and III indicate those combinations of β and M where ISP makes a non-optimal decision of not offering zero-rating plan to any CP. Since offering zero-rating plan to both CPs for those value of β and M leads to higher consumer surplus, in this case, the policymaker should intervene by allowing for zero-rating plans in these regions.

4.2.2. Total Social Welfare

The following result discusses the total social welfare, which is the sum of producer surplus of the ISP and the CPs, and the consumer surplus of both the Internet-endowed and Internet-deprived consumers under the ISP's different network management options.

Proposition 4: *Above a threshold level of Internet penetration, $\beta^{\#}(M)$, the total social welfare when the ISP offers zero-rating plan to both CPs is higher than when it does not offer zero-rating plan to any CP. This threshold level of Internet penetration varies with the relative revenue-generating capability of the two CPs.*

We explain this result by classifying geographies into very low (lower than the threshold, $\beta^{\#}(M)$), intermediate and very high level of Internet penetration.

When the level of Internet penetration in a geography is sufficiently high, consumer surplus is higher when the ISP offers zero-rating plan to both CPs than when zero-rating is not offered at all or is not incentivized enough (Proposition 3). We further explain producer surplus of CPs and the ISP at different levels of Internet penetration.

Producer surplus of the CPs depends upon the data-access price as well as the proportion of Internet-endowed and Internet-deprived population. This is because when CPs zero-rate their content, they have to zero-rate for whole population (and not just for the $(1-\beta)$ consumers). In geographies with intermediate level of Internet penetration, the ISP sets a data access price such that the CPs have incentive to zero-rate, which is beneficial both for the CPs and the consumers. Thus, producer surplus of CPs is higher when zero-rating is offered than when it is not. At intermediate level of Internet penetration, the price that the ISP charges under zero-rating may be lower or higher than the price it charges under no zero-rating. When the price charged by the ISP in zero-rating case is higher than the price charged in non-zero-rating case, the ISP benefits both from increased data-access price as well as through the increase in demand for data (from the hitherto Internet-deprived consumers). However, when the ISP charges a lower price in zero-rating case than in non-zero-rating scenario, the further reduction in price is compensated by significant increase in data demand owing to zero-rating. Thus, at intermediate levels of Internet penetration, zero-rating by both CPs has a higher total social welfare than no zero-rating at all.

In geographies with very high levels of Internet penetration, the overhead of providing zero-rated data for whole population by the CP (extra revenue is generated only from the Internet-deprived population) is compensated by the low data access price set by the ISP. Thus, CPs profit is higher when both are offered to zero-rate than when neither is offered to zero-rate. The ISP's profit, when zero-rating is offered to both CPs is lower than when zero-rating is not offered to any CP. This is because at such high levels of Internet penetration, to incentivize CPs to zero-rate, the ISP charges a very low data access price. This reduction in data price is not compensated by the proportionate increase in data demand. Overall, however, in geographies with very high level of Internet penetration, total social welfare is higher when the ISP offers zero-rating plan to both CPs than when it does not.

Finally, in geographies with low level of Internet penetration ($\beta < \beta^{\#}(M)$), consumer surplus when the ISP does not offer zero-rating plan is higher than when the ISP offers zero-rating plan to both CPs (Proposition 3). In such geographies, the price that the ISP charges when both CPs are offered to zero-rate is significantly higher than what it charges when it does not offer zero rating plan (Lemma A). Since such high prices dissuade Internet-endowed consumers from consuming even paid content and can not incentivize CPs to zero-rate, the producer surplus of CPs in such geographies is much lower when zero-rating plan is offered by the ISP than when it is not. In such a case though, the ISP will benefit from the high data-access price, thus increasing the producer surplus of the ISP. Overall, in geographies with very low level of Internet penetration, not offering zero-rating plan leads to higher total social welfare than offering zero-rating plan to both CPs.

To provide an intervention strategy to policymakers when their goal is to enhance total social welfare, we combine this result with the ISP's decisions as mentioned in Proposition 1. We present two evident conclusions on suboptimal decisions made by ISP. The ISP makes suboptimal choices under two scenarios: (i) if the ISP allows both CPs to zero rate in geographies with Internet penetration below $\beta^{\#}(M)$, and (ii) if the ISP does not allow any CP to zero rate in geographies with Internet penetration above $\beta^{\#}(M)$. Shaded area in Figure 7 illustrates the areas in $\beta - M$ plane where the policymaker needs to intervene if it wants to maximize total social welfare.

[Figure 7 about here.]

In the figure, Region I indicates those combinations of β and M values where ISP makes a sub optimal decision to offer zero-rating plan to both CPs, since not offering zero-rating plan to any CP for those values of β and M leads to higher consumer surplus. Similarly, Regions II and III indicate those $\beta - M$ combinations where the ISP makes a non-optimal decision of not offering zero-rating plan to either CP, since offering zero-rating plan to both CPs for those value of β and M leads to higher consumer surplus.

Numerical Analysis

Given the analytical complexity of the model because of the number of parameters involved, it is impossible to determine the network management choice preference that maximizes a particular objective for all values of β and M. Thus, we use numerical analysis to provide insights on the optimal choice of network preference for different values of β and M.

Theoretically, both β and M can assume any value between 0 and 1. For the numerical analysis, we approximate β to the nearest 0.05 value and M to nearest 0.01 value. Further, to conduct numerical analysis, we choose values of four exogenous parameters, λ, V(λ), t and r_H. The choice of values for these parameters is driven by the necessary conditions required for the existence of equilibrium of all cases (Cho et al. 2016). We choose parameter values as follows: V(λ) = 5, t = 2, $\lambda = 2$, $r_H = 8$. Since M is allowed to vary between 0 and 1, r_L can take any value between 0 and 8. The following results are derived based on these parameter values and show the interplay between two main factors β and M that drive the equilibrium results. We note that we have tested these results for other combinations of parameter values which satisfy the equilibrium conditions. The results hold for those cases as well.

Figure 8 indicates two sets of network management decisions of the ISP for different values of β and M: one set of decisions which are optimal for the ISP and the other set denotes decisions which maximize total social welfare. The ISP's optimal decisions are indicated by regions I to VI, which are marked by different β and M values, as per proposition 1. In Regions I, III, IV and VI, the ISP's profit maximizing decision is to not offer a zero-rating plan to any CP. In Region II, the ISP's profit maximizing decision is to offer a zero-rating plan to only the dominant CP and in region V, it is to offer zero-rating plan to both CPs. The three differently shaded regions within the figure refer to the optimal zero-rating policies for maximizing social surplus. From left, the first shaded region indicates the area where not offering zero-rating maximizes social surplus. In the second shaded region, offering both CPs to zero-rate maximizes social surplus and finally, in the third shaded region, offering only the dominant CP to zero-rate maximizes social welfare. As Figure 8 shows, the ISP's profit maximizing decision does not always align with the social welfare maximizing policy. We now discuss the intervention strategy that the policymakers should follow to maximize social welfare.

[Figure 8 about here.]

Intervention regions IV-1 to IV-3 in Figure 9 represent policymaker's regions for intervention towards the goal of maximizing social welfare. Intervention Region 1 (IV-1) in the figure indicates the area in β-M plane where the ISP's profit-maximizing decision of not allowing zero-rating plan does not maximize social welfare. The choice for maximizing social welfare in this region is to offer zero-rating to both CPs (Refer Figure 8). Intervention Region 2 (IV-2) indicates the the area where the ISP's profit-maximizing decision of choosing only the dominant CP to zero-rate is not the socially optimal choice. The optimal choice to maximize social welfare in this region is to allow both CPs to zero-rate, as inferred from figure 8. Finally, Intervention Region 3 (IV-3) indicates those values of β and M where the ISP decides to not allow zero-rating, while the socially optimal decision in that area is to either allow both CPs to zero-rate (at higher values of M) or only the dominant CP to zero-rate (for lower values of M). These regions, thus, indicate the local societal context (level of Internet penetration and level of competition among CPs) that policymakers need to consider to intervene if their goal is to maximize social welfare.

[Figure 9 about here.]

5. Discussion

This study was primarily motivated by fact that in many developing economies, where there are significant percentages of the population without meaningful Internet access, policymakers have envisaged zero-rating plans as a way to bridge the digital divide. This is distinct from the debate around such plans as to whether they go against the principles of net neutrality. However, in many countries, the two issues have been conflated, and thus, regulators in different countries have reacted very differently to zero-rating plans. The responses point to the important role that *local context* plays in deciding upon issues that are supposedly universal, like issues that have to do with Internet network management. We believe that the extent of penetration of the Internet within a market to be an important parameter which impacts the decisions of all players involved as well as the policymakers. With that in mind, our research provides a thorough economic analysis of whether zero-rating plans can be used as a tool for increasing Internet penetration, with the ISP playing the role of gatekeeper. The results thus obtained provide us with a set of guidelines that can inform the regulators under different market conditions.

The first set of findings relate to the optimal decisions that the ISP would make under different scenarios. We find that in markets with very high or very low levels of Internet penetration, not offering zero-rating plan to any CP will be the optimal choice for ISP. In geographies with intermediate levels of Internet penetration, offering zero-rating plan to either the dominant CP or both CPs is the optimal decision. The choice between whether to allow only one or both CPs to zero-rate depends upon the relative revenue generating capability of the CPs involved, i.e. the level of competitiveness between the two CPs. We find that when M is high enough, i.e. higher than a threshold, M^*, the ISP has no incentive to play the role of a gatekeeper for Internet access. Since a relatively high M implies that the two CPs are locked in close competition, the result means that in such cases, it is optimal for ISP to offer zero-rating plan to both CPs. However, when M is lower than the threshold value, the ISP will offer zero-rating plan to only the dominant CP. This result corroborates with fear of CSOs and other research performed earlier (Cho et al. 2016, van Schewick 2016) about the ISP discriminating against the less dominant CP, and point towards a possible intervention by the local regulatory bodies.

The second set of findings derive conditions towards maximizing consumer surplus of the Internet-deprived consumers, total consumer surplus and social welfare. We find that allowing any form of zero-rating plans increases the welfare of the Internet-deprived population. Comparing total consumer surplus when the ISP offers zero-rating plan to both CPs as against not offering zero-rating plan at all, we find that for geographies that have sufficiently high levels of Internet penetration (i.e., higher than a threshold), offering zero-rating plan to both CPs generates a higher total consumer surplus than not offering zero rating at all. The result is similar while comparing social welfare as well, though the threshold levels of Internet penetration for the two scenarios differ.

Considering the surfeit of parameters that we handle in solving this game-theoretic model, it is impossible for us to make conclusive statements on the dominating equilibrium. Thus, we employ numerical analysis to comment on the optimality of ISP's decision for specific areas in the $\beta - M$ plane.

The final set of findings of our research work have to do with our recommendation for policymakers. Combining the results of the ISP's network management decisions and surplus for different regions in β-M plane, the results indicate that in geographies with very high levels of Internet penetration, the ISP makes a socially sub-optimal choice of not offering zero-rating plan to any of the CPs. The decision is sub-optimal both from the perspective of maximizing consumer surplus as well as total social welfare. In case the goal of policymakers is primarily to maximize the surplus of Internet-deprived consumers, the results indicate that offering zero-rating plan to both CPs is the optimal choice. Hence, any other decision by the ISP should attract the policymaker's attention. Numerical analysis, along with corroborating evidence from the analytical results obtained, also points to the dominating equilibrium for all values of β and M. However, the numerical analysis is restricted to some specific values of the parameters used in the model.

The analysis provides a framework for policymakers to understand their local context and indicate the need for some nuanced decision-making. This is especially true as the results indicate that zero-rating plans seem to be welfare-enhancing in most contexts, especially when large swathes of the population have no access to the Internet.

6. Conclusion

Zero-rating plans are garnering a lot of attention from regulators and policy makers, firms whose business model it impacts, as well as the open society advocates, each for a different reason. Whereas firms see it as an extra revenue stream and a way to capture new segments of the market, the civil society organizations have raised the issues of freedom of expression and of anti-competition that such plans potentially bring along with them. The policy makers, especially in the developing world, therefore have a delicate decision to make, given the promise of a reduced digital divide from such plans. Since the freedom of expression is viewed as an enabler of several other basic human rights and enjoys a near-universal acceptance worldwide, the issue of zero-rating plans violating this freedom (with ISPs being able to play the role of Internet gatekeeper) has become a mainstream policy discussion topic and therefore demands a thorough analysis.

This study examines the role of ISP both in enabling the benefits of these plans as well as the extent to which they play the role of a gatekeeper if the zero-rating plans are allowed by regulators. We examine how different levels of Internet penetration and relative revenue-generating capabilities of the CPs impact the ISP's decisions and in what cases the ISP may or may not have an incentive to play the role of gatekeeper for the Internet. We also examine the impact of the ISP's decisions on consumer surplus and social welfare, and derive conditions under which the ISP will have the incentive to make sub-optimal choices and thereby arrive at our policy recommendations.

We find that for most levels of Internet penetration, zero-rating plans can be welfare-enhancing. Moreover, the optimal strategy of the ISP (when zero-rating plans are allowed) is to not always offer zero-rating to only the dominant CP, as has been feared by some of the CSOs. Given the possibility of making the Internet available to the under-served population, especially in developing economies, we find a more nuanced role of the regulators. Instead of completely banning zero-rating plans, regulators should consider the possibility that such plans could be welfare-enhancing, especially when combined with smart regulation. At the same time, this study argues that letting the market play its own role, either in allowing or not allowing zero-rating plans is often not optimal. Thus, the findings of our research has strong implications for policymakers.

For academicians, this paper fills the research gap by studying the linkage between a monopolist ISP, digital content markets and the role of contextual factors like the level of Internet penetration. Current studies in this area either completely ignore the level of the digital divide as an important contextual factor to study or have studied it as a dependent variable, i.e. the impact Internet regulations can have on the level of digital divide. Moreover, most of these studies look at the issues from the perspective of net neutrality regulations.

Considering the huge number of parameters impacting the model, we have made certain reasonable assumptions to be able to arrive at our conclusions. As in much of the extant literature, we assume that the ISP market is a monopoly and the CP market a duopoly. We also assume the same fit cost for both Internet-endowed and Internet-deprived consumers. Thus, relaxing these assumptions and testing for robustness of these results can be an interesting extension of our research. For example, considering the ISP market as a duopoly or as a perfect competition can be some interesting extensions of our research. Since zero-rating plans are frequently offered as a differentiated service, competition in the ISP market would be an important extension of this research.

Other than that, there are several other possible extensions of this work. Distinct from the zero-rating plans, the free software community Mozilla came up with the idea of equal-rating plans which also aim at expanding markets as well as closing the digital divide. Although the logistics of the plan is currently under scrutiny, a few other experiments are being floated across the world that allow the users to access any content of their choice, without curtailing their freedom of expression or choice. For example, a CP can get into an agreement with ISPs to subsidize the Internet content for end users, without restriction, after the user satisfies certain conditions like watching an advertisement or downloading an application (Yiakoumis 2015, Romanosky and Chetty 2018). Examining business ideas like these can be a next step towards understanding the role such plans can play towards achieving higher Internet penetration without compromising on the freedom of expression or choice.[4] Regardless of the directions that these plans expand in future, they will have an important role to play in reducing the digital divide in the society and provide a fertile ground for exploration among practitioners and researchers alike.

Acknowledgments

[4] Such plans, however, raise other issues like user privacy.

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Figures

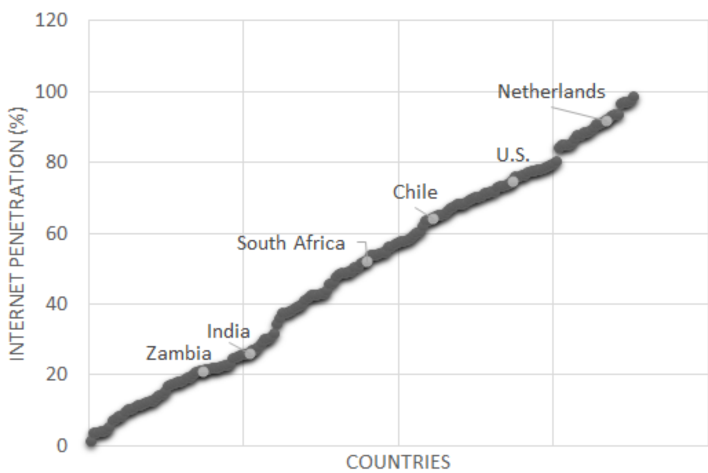

Figure 1 **Worldwide Internet Penetration (ITU, 2017)**

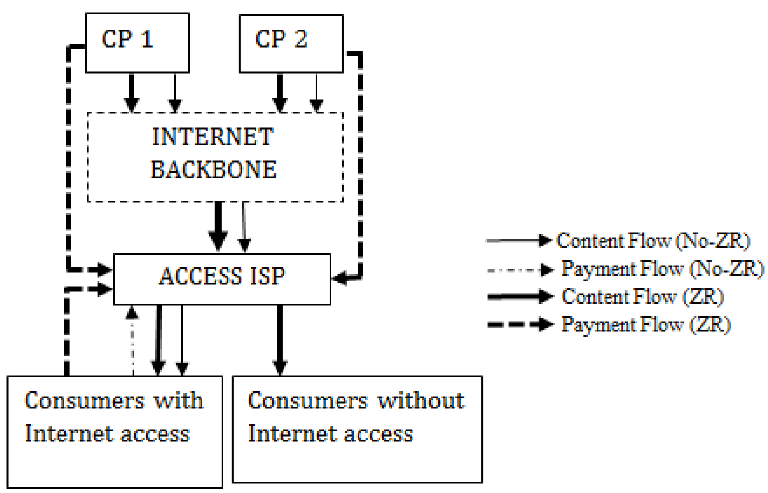

Figure 2 **How Zero-Rating Plans Work: A Schematic Diagram**

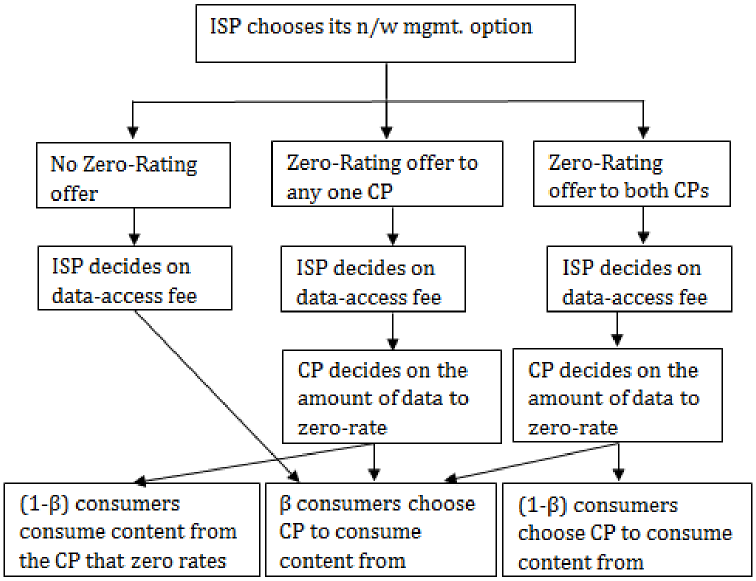

Figure 3 **Timeline of the model**

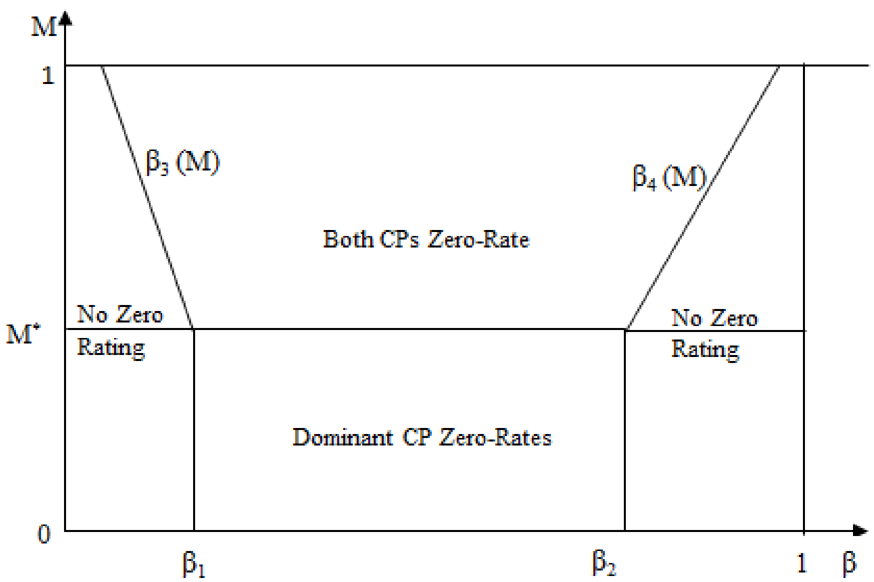

Figure 4 **ISP's Network Management Decisions**

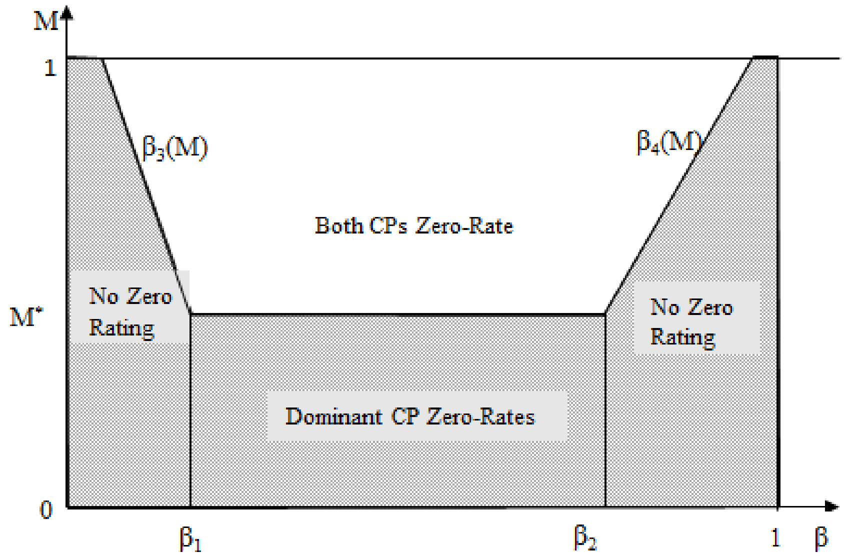

Figure 5 **Policymaker's Intervention: Maximize Internet Penetration**

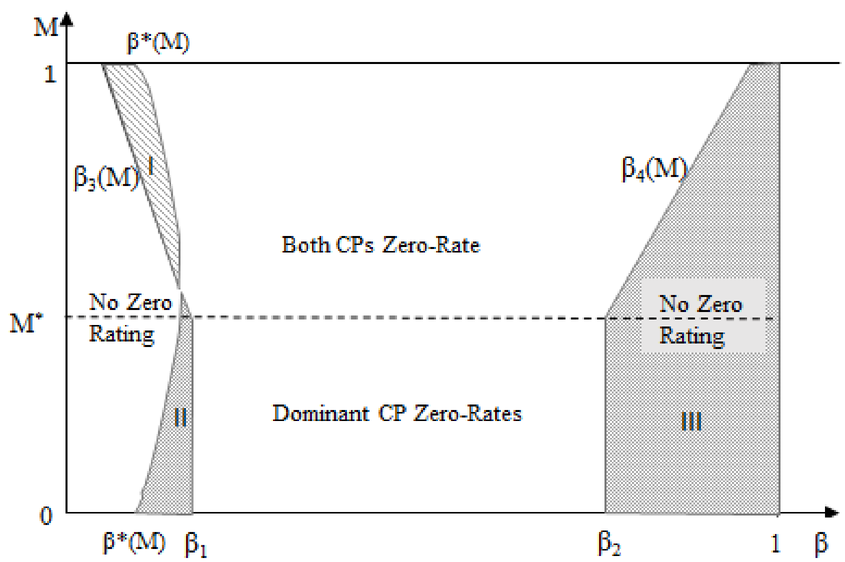

Figure 6 **Policymaker's Intervention: Maximize Total Consumer Welfare**

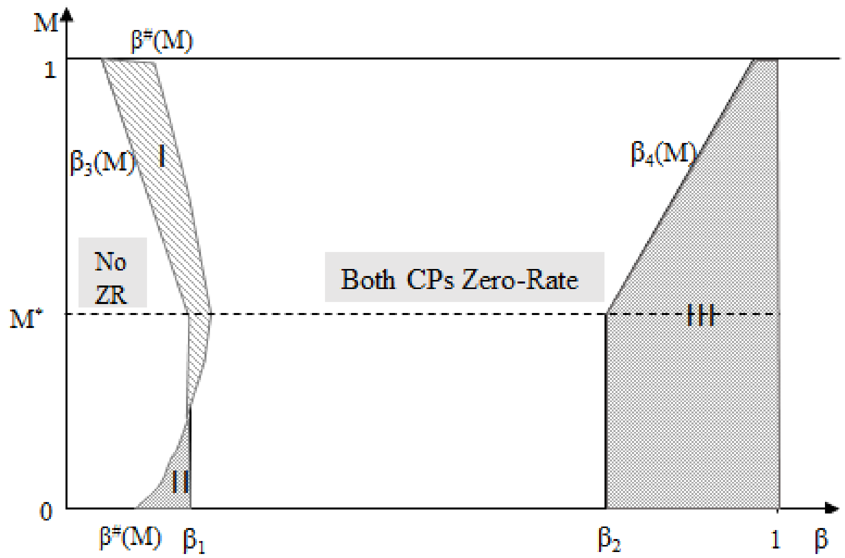

Figure 7 **Policymaker's Intervention: Maximize Total Social Welfare**

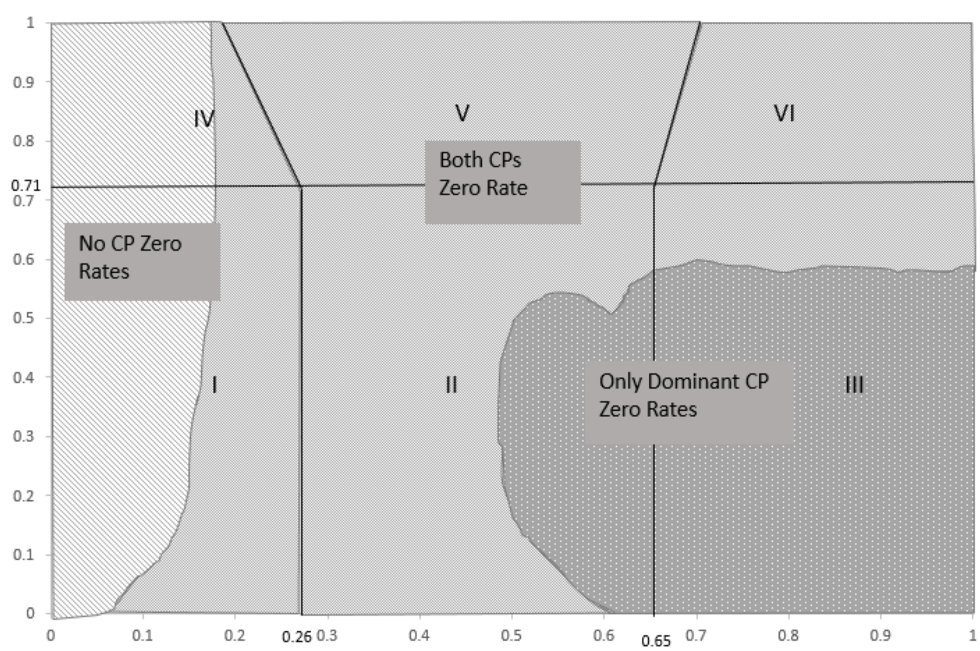

Figure 8 **Optimal Decisions for Maximizing Social Surplus**

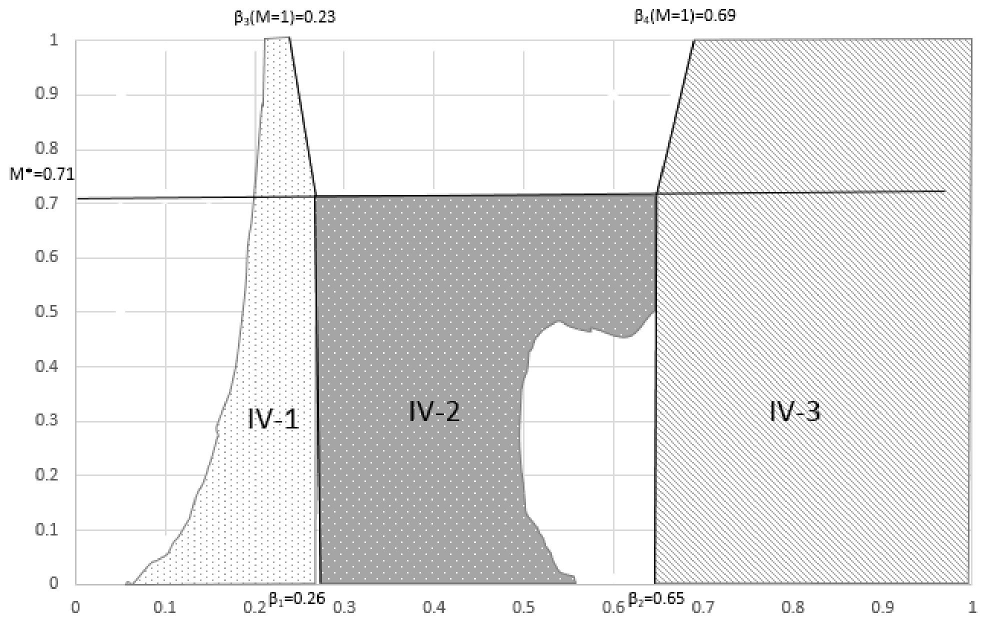

Figure 9 Policymaker's Intervention (Numerical Analysis): Total Social Welfare

Tables

Case	I_L/I_H	**Interpretation**
Case 1	$I_L = I_H = 0$	Neither CP L nor CP H is offered zero rating
Case 2	$I_L = 1; I_H = 0$	Only CP L is offered zero rating
Case 3	$I_L = 0; I_H = 1$	Only CP H is offered zero rating
Case 4	$I_L = I_H = 1$	Both CP L and H are offered zero rating

Table 1 ISP's Network Management Options

Notations	**Description**
p_j	Usage-based price ISP charges to consumers or to CPs L and H for their zero-rated content; j denotes the different network management options of the ISP
t	Fit cost parameter for an end consumer away from the content that is perfectly fitted with her preference
λ	Poisson arrival rate of content requested
β	Proportion of population with meaningful Internet access
$\lambda_{s,L}, \lambda_{s,H}$	Poisson arrival rate of content from CPs L and H, subsidized for each consumer in packets per unit of time
r_L, r_H	Revenue generating capability of the CPs L and H respectively
$M = \frac{r_L}{r_H}$	Ratio of the revenue generating capabilities of CPs L & H
I_L, I_H	Indicator function indicating whether ISP offers zero rating to CP L or CP H, respectively
U_L^{β}, U_H^{β}	Consumer's utility function of Internet-endowed consumers when consuming content from CP L and H respectively
$U_L^{1-\beta}, U_H^{1-\beta}$	Consumer's utility function of Internet-deprived consumers when consuming content from CP L and H respectively
$x^{\beta}, x^{1-\beta}$	An arbitrary consumer on [0,1] content preference spectrum from Internet-endowed and Internet-deprived consumers respectively
$\bar{x}^{\beta}, \bar{x}^{1-\beta}$	Marginal consumer who is indifferent between CP L and H in equilibrium, from Internet-endowed and Internet-deprived consumers respectively
π_L, π_H	CP L and H's profit, respectively
π_{ISP}	ISP's profit
D_L^{β}, D_H^{β}	Market base of CP L and H respectively, from the Internet-endowed population
$D_L^{1-\beta}, D_H^{1-\beta}$	Market base of CP L and H respectively, from the Internet-deprived population
$V^{\beta}(\lambda)$	Gross value function of retrieving content for each consumer from Internet-endowed population
$V^{1-\beta}(\lambda)$	Gross value function of retrieving content for each consumer from Internet-deprived population

Table 2 List of Notations

ISP's Choice	β **Consumer**	$(1-\beta)$ **Consumer**
No CP offered zero rating	$\frac{1}{2}$	NA
CP L offered zero rating	$\frac{1}{2} + \frac{p\lambda_{s,L}}{2t}$	1
CP H offered zero rating	$\frac{1}{2} - \frac{p\lambda_{s,H}}{2t}$	0
Both CPs offered zero rating	$\frac{1}{2} + \frac{p(\lambda_{s,L}-\lambda_{s,H})}{2t}$	1/2

Table 3 Marginal Consumer

ISP's Choice	**Optimal Price**
No CP offered zero-rating plan	$\frac{2V(\lambda)-t}{2\lambda}$
CP L offered zero-rating plan	$\frac{(1-\beta)}{\beta}\sqrt{\frac{r_L t}{\lambda}}$
CP H offered zero-rating plan	$\frac{(1-\beta)}{\beta}\sqrt{\frac{r_H t}{\lambda}}$
Both CPs offered zero-rating plan	$\frac{(1-\beta)}{\beta}\sqrt{\frac{(r_L+r_H)t}{2\lambda}}$ or $\frac{(1-\beta)}{\beta}\sqrt{\frac{r_H(M+1)t}{2\lambda}}$

Table 4 ISP's Optimal Price Strategy