# Role of Digital Divide in Optimal Zero Rating Policy

*Completed Research Paper*

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**Abstract**

*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 open-access advocates have decried these plans, arguing that they are anti-competitive, ISPs and CPs argue that such initiatives enable Internet-deprived segments of society to finally be able to access the Internet. Our work looks at this issue in the presence of digital divide. We analyze ISP's and 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. Our research finds that zero-rating plans can enhance social welfare for most levels of digital divide. However, Internet regulators need to be vigilant, since the ISPs may sometime deviate from a strategy that maximizes social welfare. The study has implications for policymakers, particularly those, for whom increasing Internet penetration remains a crucial goal.*

**Keywords:** zero rating, Internet service provider, Internet penetration, content provider, subsidization, Internet data policy

## Introduction

In December 2017 US 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 speculations about the impact of this decision on rest of the world. In India, TRAI (Telecom Regulatory Authority of India)'s chairman mentioned that their overarching goal was to keep the Indian context in mind. 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 context (specifically, the extent of Internet penetration) on zero-rating regulatory decisions.

Research shows that access to Internet increases the welfare and well-being of its users through efficiency gains and improvements in service quality in fields of health, education, empowerment, etc. (ITUReport, 2017). Therefore, increasing Internet penetration remains as one of the most crucial goals for policymakers across the world. Although continuous 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, in Africa Internet penetration touches down to 18% with the world average being 48%. Given the far reaching impact of Internet, there is great interest among the policymakers to bridge this gap.

To achieve this goal, governments across the world launch various programs, for example, India's Digital India plan (GoI, 2018) and the U.S. government's National Broadband Plan (NBP). Although zero-rating plan is posed as a potent tool to accomplish higher Internet penetration, it is laden with controversies like restricting freedom of expression and gate-keeper role of the Internet that ISPs may attain. This paper examines whether zero-rating plans can increase Internet penetration while being vigilant of its sticky issues.

Zero-rating (ZR) 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 1 illustrates the difference between a usual data-plan and a zero-rated plan. The figure differentiates between consumers who can afford to pay for the Internet (Internet-endowed henceforth) and thus having access to it and Internet-deprived consumers who cannot afford to pay for the Internet and have access to it only when zero-rating is allowed.

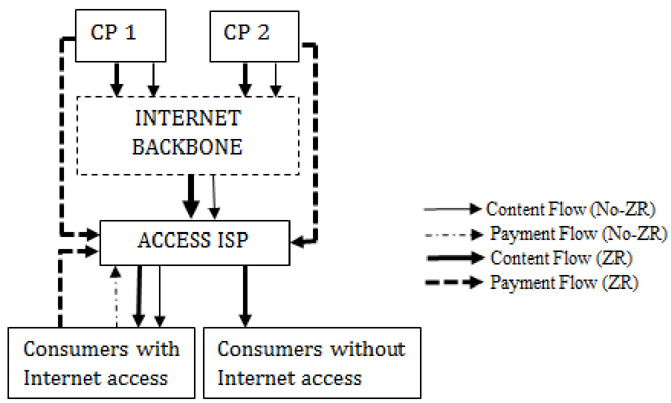



Figure 1: How Zero-Rating Plans Work: A Schematic Diagram

Both ISPs and CPs pose zero-rating plans as an instrument towards achieving universal Internet access and offer to launch these ZR plans as a part of their corporate social responsibility initiatives. Several consumer organizations question this altruistic justification and claim it to be just another tactic to increase their customer base while compromising on the freedom of expression of end consumers (Imtiaz, 2014). Policymakers across the world, stuck at an impasse owing to such varied arguments, have responded to such offers by ISPs and CPs differently. In U.S., FCC has decided to keep a close watch on the plans (Ebersole, 2016). India, on the other hand, after opening a consultation paper to public for their views and inputs (IndianExpress, 2015), has banned such plans since February 2016 (Guha & Aulakh, 2016).

Debates such as net neutrality and zero-rating plans require thorough economic analysis to be able to make recommendations to the policymakers. Thus issues like these are being studied by various research streams such as economics (Economides & Hermalin, 2012), information systems (Cheng, Bandyopadhyay, & Guo, 2011), human rights (Carrillo, 2016), operations management (Guo & Easley, 2016) etc. Few studies among these analyze zero-rating plans specifically (Cho, Qiu, & Bandyopadhyay, 2016; Zhang, Wu, & Wang, 2016; Pang, Gao, Ding, & Sun, 2017). However, none of these studies examine the role that context (Internet penetration, in particular) can play on the impact of zero rating plans on society.

We find that in countries with very high or very low levels of Internet penetration, ISP's optimal choice is to not offer zero-rating to any content provider. However, in countries with intermediate level 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 countries with Internet penetration above a threshold level, ISP's choice of not offering zero-rating to any CP will be sub-optimal. Thus, our research findings argue for a more nuanced decision making for regulators on zero rating plans.

In following sections we discuss the latest academic conversation on the topic followed by model details and the results obtained with their analysis. We then discuss propositions of interest and the research' contribution towards guidelines for policymakers and academic body of work under network management.

## Literature Review

Most of the research 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 & Hermalin, 2012). Various aspects analyzed under this stream of research includes the link between net neutrality and various issues of interest like content innovation (Guo & Easley, 2016), broadband market coverage and innovation (Guo, Cheng, & Bandyopadhyay, 2012). Although zero rating plans do not involve paid prioritization of CP's data, the debate on whether ZR plans violate net neutrality is still an open question. Various open-access advocates and civil society organizations (CSOs) argue for ZR plans being a violation of net-neutrality and hence a special case of net-neutrality (Finley, 2017). Thus, literature on zero-rating plans is scant.

Zhang et al. (2016) 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 differing impact on bandwidth utilization, CP's profit and users' welfare. Such plans are found to benefit all the parties involved in it and is put forward as a potential contender for being allowed by the regulators. Another study shows how deregulation of subsidization could increase an access 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 access ISP market is not competitive enough (Ma, 2014). A few researchers introduce the concept of edge caching (cache video content on edge networks in advance and deliver the cached contents to local video users directly, without involving cellular data cost for users) will impact the CP's data sponsoring strategy as well as users' behavior and data market (Pang et al., 2017). Cho et al. (2016) develop a game-theoretical model to examine ZR plans to analyze the effect of sponsorship of consumer usage data. They examine the dependence of ISP's network management choice on revenue rates of the CPs and fit cost of customers. They also identify conditions under which these choices deviate from social optimum. Most of the work under content subsidization strategy concerns finding variations of ZR plans, however, all these studies assume complete Internet market penetration.

Another stream of research on zero-rating caters to the freedom of expression debate while viewing it through a human rights perspective (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. Thus a constructive contextual analysis is advised 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: (1) Cho et al. (2016)'s game-theoretic analysis of ZR, (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 ZR plans to analyse the effect of sponsorship of consumer data usage. The study assumes complete Internet penetration which we relax in this research work. Guo et al. (2012) examine the impact of net neutrality regulations on broadband coverage for the end consumers. Our paper differs from this in three ways. First, we specifically analyze zero-rating regulations, i.e. no data prioritization is involved. Second, while they acknowledge different levels of Internet penetration in different societies and study the impact that these regulations can have on broadband Internet penetration, we model Internet penetration to examine how these different levels impact the decisions of ISP, CPs and 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 hence are able to make more generalized claims.

## 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.

### 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 (ZR) plans, agreement between ISP and CPs allows consumers to have free access to limited data on the Internet. Initially, the ISP decides on its network management options. 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. 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. 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: ISP's Network Management Options

| **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 |

### 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 CPs in the model are at the two extreme ends of this spectrum, CP L at 0 and CP H at 1.

We assume CPs provide their content free of cost to consumers while earning their revenue from advertisers based on the number of consumers on their websites. Thus, each CP's goal is to get as many consumers to visit their websites as possible. We also assume that the two CPs differ in their revenue generating capabilities. Without loss of generality, we assume CP H has an ability to generate higher revenue per packet consumed as compared to CP L. M denotes relative revenue generating capability of the two CPs as a ratio of their independent revenue generating capabilities, whose value lies between 0 and 1.

When ISP offers zero rating plan to CPs, CP chooses the amount of content to subsidize, $\lambda_{si}$, $i \in \{L, H\}$ to its consumers. When CPs choose to subsidize $\lambda_{si}$ content, they must do so for all its consumers irrespective of whether they are Internet-endowed or Internet-deprived.

Table 2: List of Notations

| 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 |
| $\lambda$ | Poisson arrival rate of content requested |
| $\beta$ | 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 |
| $U_L^{\beta}, U_H^{\beta}$ | 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 |
| $\pi_L, \pi_H$ | CP $L$ and $H$'s profit, respectively |
| $\pi_{ISP}$ | ISP's profit |
| $D_L^{\beta}, D_H^{\beta}$ | 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 |

## Consumers

We assume that there is a unit mass of consumer that 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, $\beta$ 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, i.e. Internet-deprived consumers. 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 $x^{\beta}$ ($x^{1-\beta}$) respectively. We assume $x^{\beta}$ ($x^{1-\beta}$) to be uniformly distributed over [0,1].

Though Internet-endowed consumers have access to Internet at the beginning of the game, they still have to pay to consume it. We assume that each $\beta$ consumer has a constant demand for Internet content, $\lambda$. For every network management option that the ISP can choose, $\beta$ consumers must decide which CP to consumer 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.

Internet-deprived (1-$\beta$) 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 ZR plan. Thus, demand for Internet data is not constant from $(1-\beta)$ consumers and depends upon the amount of content zero rate by the CPs. When only one CP offers zero rated data, all of (1-$\beta$) consumers consume content from that CP only. When both CPs offer zero rating, Internet-deprived consumers consume content from any of the CPs.

## Timeline of the model

To begin with, the monopolist ISP first decides on its network management option. ISP can offer zero rating plans to one or both or none of the CPs. Subsequent to this decision, the ISP also decides on per-packet data access price 'p' that it will charge to either consumers or CPs. Next, conditional on being offered the option to zero rate, CPs decide on how much data to subsidize to consumers. After this decision, consumers choose which CP to consume its content from.

## Players' Pay-offs

### ISP's Profit

ISP's profit is a function of data access price, 'p' that it charges and 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 consumers. For each such consumer, ISP receives $p$ per unit of Internet data consumed. It receives this amount either directly from the consumer (when no zero rating is offered) or partly from consumer and CPs (when ISP offers zero-rating). The second term is the revenue generated from Internet-deprived consumers. Demand from these consumers emanates only when the ISP offers zero rating plan to at least one of the CPs and the CP subsidizes non-zero amount of data for consumers. ISP is assumed to have zero marginal cost.

### Content Provider's Profit

CPs' profit is a function of expected demand for data, 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 is:

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

In the above profit expression $\pi_i$, the first term represents revenue generated from Internet-endowed consumers who choose to consume content from CP $i$. From each of these consumers, CP $i$ receives revenue $r_i\lambda$. If CP $i$ is offered zero rating plan, then it subsidizes $\lambda_{s,i}$ packets of Internet data. Therefore, it pays $p * \lambda_{s,i}$ per $\beta$ consumer that consumes from CP $i$, to the ISP. The second term is the revenue generated from Internet-deprived consumers, when CP $i$ is allowed to zero rate. 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 $(V^{\beta}(\lambda))$, disutility cost incurred from the difference between consumer's preferred and consumed content and cost of Internet data access. Thus, utility of an Internet-endowed consumer when he consumes content from CP L or CP H is 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 its ideal content, and is borrowed from the Hotelling's framework (Hotelling, 1929). Third term is the data access cost. In cases when CPs are offered zero rating plan, this cost is reduced by the amount of data units that CPs subsidize.

Since Internet-deprived consumers access content only when ISP offers zero rating plan to CPs, they do not incur any data access cost. Thus, utility of Internet-deprived 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 gross valuation of the content for $(1-\beta)$ consumers is assumed to be constant since these consumers have never been exposed to Internet before this point in time[1].

## RESULTS & ANALYSIS

We solve for subgame perfect Nash equilibria of this game. We first solve consumers' problem of choosing which CP to choose content from. Then, we solve for the amount of data that CPs zero-rate, $\lambda_{s,i}$. 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 ISP's problem to choose price per packet, $p$ given its network management options as:

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

subject to:

$$0 \le \bar{x}^{\beta}, \ \bar{x}^{(1-\beta)} \le 1 \quad (1)$$

$$0 \le \lambda_{s,i} \le \lambda \quad (2)$$

$$U_i^{\beta}(x) \ge 0, \forall x \le \bar{x}^{\beta} \text{ when i=L}, \ \forall x \ge \bar{x}^{\beta} \text{ when i=H} \quad (3)$$

$$U_i^{1-\beta}(x) \ge 0, \forall x \le \bar{x}^{1-\beta} \text{ when i=L}, \ \forall x \ge \bar{x}^{1-\beta} \text{ when i=H} \quad (4)$$

$$\pi_L(\lambda_{s,L}) \ge 0, \ \pi_H(\lambda_{s,H}) \ge 0 \quad (5)$$

Here, constraint (1) indicates that the marginal consumer is within the range. Constraint (2) indicates that at most CPs subsidize the entire content consumed by consumers. Constraints (3), (4) and (5) specify participation constraints of marginal (Internet-endowed, Internet-deprived) consumers and CPs respectively.

***Lemma A***: *When 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, $\beta$, i.e. $p \propto \frac{1}{\beta}$. On the other hand, when zero rating is not offered, the data access price is independent of $\beta$.*

In a country where Internet penetration is high i.e. high $\beta$, CPs incentive to zero-rate decreases. This is because for a unit increase in expected revenue from Internet-deprived consumers, CPs will have to bear the cost of zero-rating the entire population. Thus, in such a country, to incentivize CPs to zero-rate, the ISP will have to charge a price lower than in a country where Internet penetration is lower. Higher the Internet penetration, lower the data access price that ISP will charge to incentivise 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 incentivised to consume the Internet content. Since the utility of the Internet-endowed consumers is independent of the level of Internet penetration, data access price in this case is independent of $\beta$. Table 3 indicates optimal price of the ISP under the four network management options that it has. These prices for ISP's specific options solves the ISP's profit maximization problem.

[1] The constant gross value may vary over time and also from consumer to consumer, however, for a specific consumer at a given time, it is assumed to be constant

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

Table 3: ISP's Optimal Price Strategy

The pricing strategy of ISP implies that in countries below a certain level of Internet penetration, ISP's optimal price when it allows zero-rating will be higher than when it does not allow zero-rating. In contrast, for countries above that level of Internet penetration, the converse is true, i.e. ISP's optimal data access price when it allows zero rating will be lower than when it does not allow zero rating.

***Lemma B****: Of the network management options that ISP has, its optimal data access price is highest when it offers zero-rating to only the dominant CP.*

ISP's revenue depends upon data access price and data demand. The data demand from $\beta$ consumers is inelastic. For $(1-\beta)$ consumers, it is highly elastic, and is same as the amount of data that CPs are willing to zero-rate. When ISP offers zero-rating to only the dominant CP, given its higher revenue generating capability, the ISP can charge higher price, just small enough to incentivize him to zero-rate. In all other zero-rating cases, ISP will have to lower the price to incentivize the less dominant CP to zero rate. However, when ISP offers zero-rating to both CPs, competition between the two CPs to acquire bigger market share allows the ISP to charge higher price than when only the less dominant CP is offered zero-rating.

## *ISP's Network Management Options*

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

- For very high and very low levels of Internet penetration, ISP does not offer zero-rating to any CP, whereas for intermediate values of $\beta$, it offers zero-rating to either one or both the CPs.
- The choice between whether to offer zero-rating to one or both CPs depends upon the relative revenue generating capability of the two CPs, M. For M less than a threshold $M^*$, ISP offers zero-rating to only the dominant CP whereas for higher value of M, ISP offers zero-rating to both the CPs [2].

Figure 2 presents these findings. Derivation of threshold values is available in full version of the paper.

**High levels of Internet Penetration**

In countries with substantially high Internet penetration ($\beta \geq \beta_2$), to incentivize CPs to zero-rate, ISP has to charge a relatively low data access price (Lemma A). On one hand charging a low price will lead to an increase in data traffic from relatively small Internet-deprived consumers but on the other hand, it will also lead to lower revenue from Internet-endowed consumers (because of lower data acces price). For substantially high $\beta$, the increase in traffic from the small Internet-deprived consumers is not high enough to compensate for lower revenue from the Internet-endowed consumers. Thus, it is not beneficial for the ISP to offer zero-rating in such economies.

**Low levels of Internet Penetration**

[2] The ISP never has incentive to choose only CP L to zero-rate

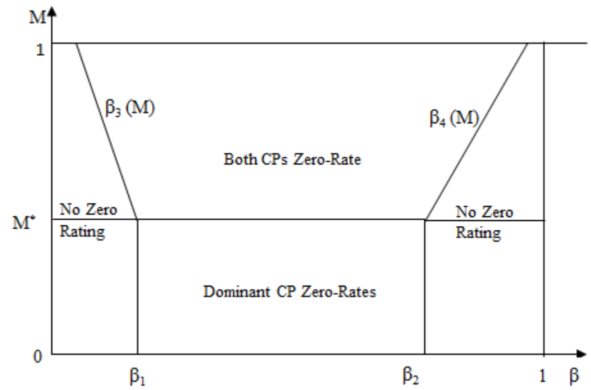



Figure 2: ISP's Network Management Decisions

In countries with very low level of Internet penetration ($\beta \leq \beta_1$), the optimal data price that the ISP charges when it offers zero rating is much higher than when it does not offer zero-rating. At such high price the CPs do not have an incentive to zero-rate as the data access price per packet is more than the CPs' revenue generating capability. Moreover, for such high price, the utility of Internet-endowed consumers is also negative, dissuading them from accessing Internet. Thus, at very low levels of Internet penetration, the ISP will choose to not offer zero-rating to any CP.

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

In countries with intermediate levels of Internet penetration, the optimal price at which the ISP offers ZR to CPs may be higher or lower than the data access price when no zero rating is offered to any CP. When zero-rating price is higher than non zero-rating price, then the ISP benefits both by higher price as well as additional data traffic generated because of zero-rating incentivising the ISP to zero rate. In contrast, when the ISP's optimal data access price in ZR case is lower than non-zero rating case, the loss because of lower price is compensated by much higher data traffic owing to higher amount of data being subsidized. Therefore, in countries with intermediate levels of Internet penetration, ISP has 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. When ISP offers zero-rating to both CPs, the amount also crucially depends upon the data zero-rated by the other CP. Low M implies the revenue generating capability of one CP (CP L) is much lower than that of other CP (CP H). For low M, CP L zero-rates much lesser data than CP H. In this case if 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 the dominant CP is offered zero rating, the amount of data that it zero rates is not constrained by CP L's zero-rated data amount.

High M implies that the revenue generating capabilities of the two CPs are comparable. Thus, if both CPs are offered ZR, competition among them leads to much higher ZR content. Although the data access price charged by the ISP when both the CPs are offered ZR 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 price.

## *Welfare Analysis*

Here we analyze how 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. Through this analysis, we find conditions for when the policymaker, depending upon the objective of social planner, should intervene.

**Consumer Surplus Analysis**

The following two propositions discuss the optimal choice of social planner when its objectives are increasing Internet penetration and total consumer surplus. By total consumer surplus, we imply combined consumer surplus of Internet-endowed as well as Internet-deprived population.

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

When ISP does not offer zero-rating to any CP, Internet-deprived consumers remain without any Internet access. Thus the Internet penetration is least in this case. Every other network management decision of the ISP leads to complete Internet penetration. However, when ISP offers zero-rating to both CPs, along with access to the Internet data, the Internet-deprived population also have choice regarding which CP to choose data from. 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 to both the CPs.

To provide intervention strategy to policymakers, we combine this result with Proposition 1 which illustrates ISP's optimal choices for different combinations of $\beta$ and M. To maximize Internet connectivity among the hitherto Internet-deprived population, ISP's decision of not allowing zero-rating is sub-optimal in all countries for any level of relative revenue generating capability of the two CPs. Moreover, if policymaker also intends to provide choice to the Internet-deprived population, of CPs from whom to consume data, it should intervene for any network management decision of ISP which does not offer zero-rating to both CPs.

Figure 4 illustrates the areas (shaded) in $\beta$-M plane where policymaker needs to intervene, given that its sole goal is to increase Internet penetration.

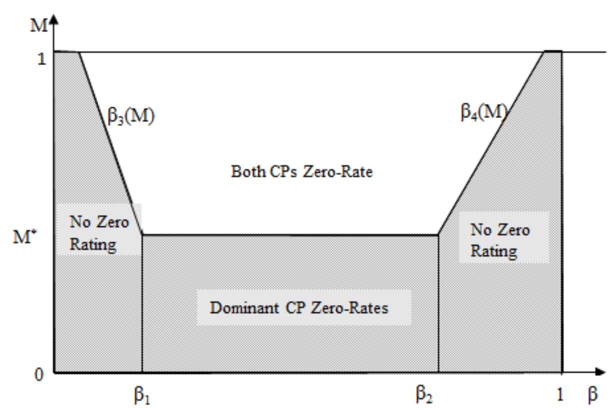



Figure 3: Policymaker's Intervention: For Enhancing Internet Penetration

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

In countries with low Internet penetration ($\beta < \beta^*(M)$), the optimal price at which ISP offers zero-rating to CPs is very high. At this price, the utility of Internet-endowed consumers is zero because of increased payout for data access. This dis-incentivizes 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 than when no ZR is offered.

In countries with high Internet penetration ($\beta \geq \beta^*(M)$), the optimal price at which ISP offers zero-rating to CPs is low. This low price incentivizes CPs to zero rate increasing the surplus of both

Internet-endowed and Internet-deprived consumers because of higher subsidized data. The lower price also increases the utility of Internet-endowed consumers further by reducing their pay-out towards paid data access. Therefore, when $\beta$ is high, consumer surplus is higher when both CPs are allowed to zero rate.

**Intervention Strategy**: We present two evident conclusions on the non-optimal decisions made by the ISP. ISP makes non-optimal decisions in two scenario: (i) if ISP allows both CPs to zero rate in countries with Internet penetration below $\beta^*$, and (ii) if the ISP does not allow any CP to zero rate in countries with Internet penetration above $\beta^*$. Shaded area in Figure 4 illustrates the areas in $\beta$-M plane where the policymaker needs to intervene if it wants to maximize consumer surplus. Region I indicates area where ISP makes a non-optimal decision to offer zero rating to both CPs, since not offering zero rating to any CP for those value of $\beta$ and M leads to higher consumer surplus. Regions II and III indicate areas where ISP makes a non-optimal decision of not offering zero rating to any CP, since offering zero rating to both CPs for those value of $\beta$ and M leads to higher consumer surplus.

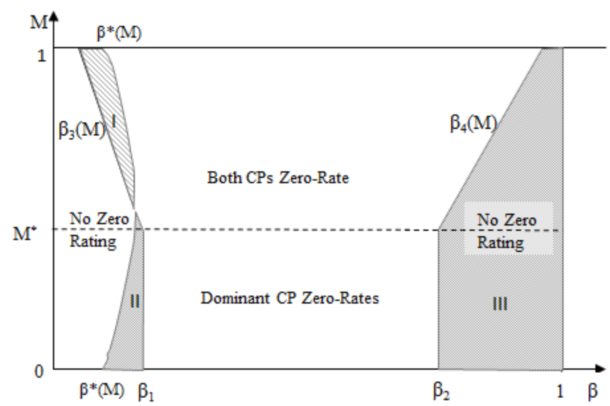



Figure 4: Policymaker's Intervention: Total Consumer Welfare

**Total Social Welfare**

The following result discusses total social welfare, which is the sum of producer surplus of ISP, CPs and consumer surplus of both Internet-endowed and Internet-deprived consumers.

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

At higher levels of Internet penetration, consumer surplus is higher when ISP offers zero rating to both CPs than when zero rating is not offered (Proposition 3). Producer surplus of CPs depends upon the data access price as well as the proportion of Internet-endowed and Internet-deprived population. In countries with very high levels of Internet penetration, the overhead of providing zero-rated data for whole population (for extra revenue only from the Internet-deprived population) is compensated by the low data access price set by the ISP. ISP's profit part of producer surplus 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, in countries with very high level of Internet penetration, total social welfare is higher when the ISP offers zero-rating to both CPs than when it does not.

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

**Intervention Strategy:** We present two evident conclusions on non-optimal decisions made by ISP. The ISP makes non-optimal choices in two scenario: (i) if ISP allows both CPs to zero rate in countries with Internet penetration below $\beta^{\#}(M)$, and (ii) if the ISP does not allow any CP to zero rate in countries with Internet penetration above $\beta^{\#}(M)$. Shaded area in Figure 5 illustrates the areas in $\beta - M$ plane where the policymaker needs to intervene if it wants to maximize total social welfare. Region I indicates area where ISP makes non-optimal decision to offer zero rating to both CPs, since not offering zero rating to any CP for those value of $\beta$ and M leads to higher consumer surplus. Similarly, Regions II and III indicate area where ISP makes a non-optimal decision of not offering zero rating to any CP, since offering zero rating to both CPs for those value of $\beta$ and M leads to higher consumer surplus.

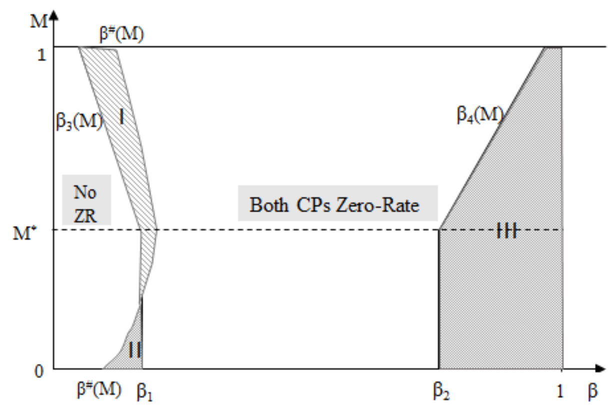
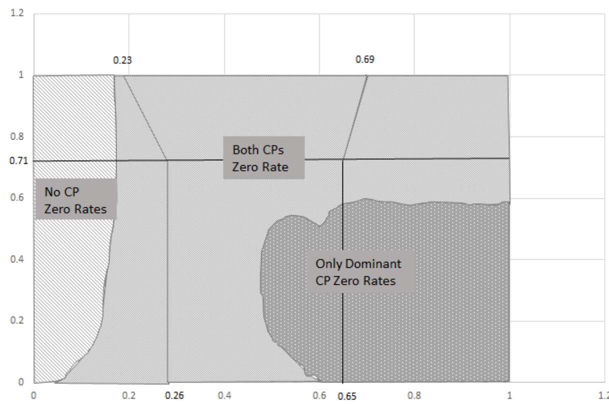


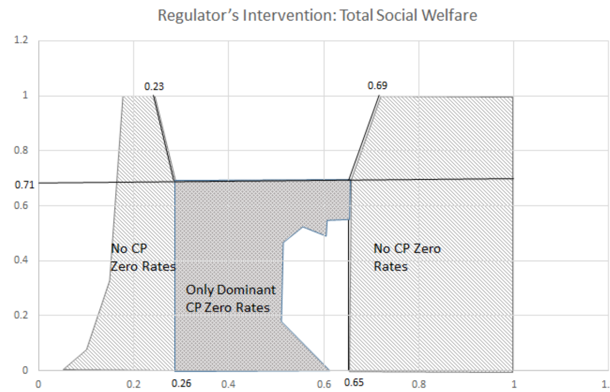

Figure 5: Policymaker's Intervention: Total Social Welfare

Given the analytical complexity owing to the number of parameters involved, it is impossible to determine the network management choice that maximizes different objectives for all values of $\beta$ and M. Thus, we use numerical analysis to provide insights on the optimal choice of network preference for different values of $\beta$ and M. Theoretically, both $\beta$ and M can assume any value between 0 and 1. However, for the numerical analysis, we approximate continuous parameter $\beta$ to the nearest 0.05 value and continuous parameter M to nearest 0.01 value. Further, to conduct numerical analysis, we choose values of four exogenous parameters, $\lambda$, V($\lambda$), 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($\lambda$) = 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 $\beta$ and M that drive equilibrium results. We have tested these results for other combinations of parameter values which satisfy the equilibrium conditions.

Figure 6a indicates two sets of network management decisions of ISP, one set of decisions which are optimal for the ISP and the other which maximize total social welfare. ISP's optimal decisions are indicated




(a) Optimal Decisions: Maximizing Social Surplus




(b) Policymaker's Intervention:Total Social Welfare

by regions I to VI, which are differentiated by $\beta_1$ (0.26), $\beta_2$ (0.65), $\beta_3(M=1)$ (0.23), $\beta_4(M=1)$ (0.69) and $M^*$ (0.71). Thus in Region I, III, IV and VI, the ISP does not offer zero-rating to any CP. In Region II, ISP offers zero rating to only the dominant CP and in region V, ISP offers zero rating to both CPs. The decisions which maximize total social welfare are denoted by different shades in the figure.

Figure 6b indicates the regions where policymakers need to intervene if its goal is to maximize social welfare. Region I indicates the area where the ISP's decision of not allow zero-rating is not the optimal for maximizing social welfare. Similarly, Region II indicates the area where the ISP's choice of choosing only the dominant CP to zero-rate is not the optimal choice. Region III indicates the area where the ISP decides to not allow zero rating as against the social welfare enhancing decision of choosing either both (for higher M) or only the dominant CP (for lower M).

## Conclusion

This study is primarily motivated by the disparate response that ZR plans are getting from across the countries of the world. The responses point to the important role that local context plays in such universal Internet network management issues. We consider Internet penetration as an important contextual parameter which may impact impact the decisions of all players involved. Therefore, we study the role of the level of Internet penetration, $\beta$ and relative revenue generating capability of the CPs, M in decision making of various players.

The findings indicate ISP's optimal network management decisions which constitutes which CP to offer zero-rating and the optimal data-access price. The study also performs welfare analysis and lays out conditions on when those decisions may or may not be optimal. This optimality is measured from the perspective of Internet penetration, total consumer surplus and total social welfare. Based on these results (ISP's optimal decisions and social welfare analysis), we offer intervention recommendation for policymakers. The results obtained provide a framework for policymakers to understand their context where the decision needs to be taken to take a nuanced decision. As we see that zero rating plans seem to be welfare-enhancing in most contexts, especially when large swathes of population has no access to the Internet. Thus, the research work has strong implications for policymakers. This paper fills the research gap by studying the linkage between a monopolist ISP, markets of digital content and the role of contextual factor like the level of Internet penetration altogether.

Considering the huge number of parameters impacting the model, we have made certain reasonable assumptions to be able to arrive at generalized conclusions. These assumptions remain the limitations of this research work which include assuming ISP market as a monopoly and all consumers having a fixed demand for content, $\lambda$. Thus, relaxing these assumptions (for example, endogenizing $\lambda$ and considering ISPs market as duopoly or perfect competition) point to future direction of our work.

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