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Robert Somogyi

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The Economics of Zero-rating and Net Neutrality

Robert Somogyi *

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Abstract

This paper studies zero-rating, an emerging business practice consisting in a mobile internet service provider (ISP) excluding the data generated by certain content providers (CPs) from its consumers' monthly data cap. Being at odds with the principle of net neutrality, these arrangements have recently attracted regulatory scrutiny all over the word. I analyze zero-rating incentives of a monopolistic ISP facing a capacity constraint in a two-sided market where consumption provides utility for homogeneous consumers as well as advertising revenue for CPs. Focusing on a market with two CPs competing with each other and all other content which is never zero-rated, I identify parameter regions in which zero, one or two CPs are zero-rated. Surprisingly, the ISP may zero rate content when content is either very unattractive or very attractive for consumers, but not in the intermediary region. I show that zero-rating harms consumers if content is unattractive, whereas it improves social welfare in the case of attractive content.

JEL Classification: D21; L12; L51; L96

Keywords: Zero-rating; Sponsored Data; Net Neutrality; Data Cap; Capacity Constraint

*CORE, Université catholique de Louvain. Email address: robert.somogyi@uclouvain.be.

1 Introduction

Zero-rating is a commercial agreement between a mobile internet service provider (ISP) and a content provider (CP) excluding the CP's data from users' monthly data cap. A typical example is T-Mobile US's Binge On program, under which T-Mobile's users can watch an unlimited amount of Youtube and other videos through the 4G network as doing so does not count against their data caps. This practice constitutes a violation of the **net neutrality** principle as not all data packages are treated equally, some count against users' data cap and some do not. Moreover, zero-rating has become a widespread practice: a study in 2014 covering 180 mobile carriers serving 2.4 billion customers worldwide found that **49% of mobile carriers** engage in some form of it (Allot Communications, 2014). Accordingly, net neutrality in general and zero-rating in particular are of considerable **interest to both regulatory agencies and the general public**. For instance BEREC, the EU's regulatory body of telecommunication, received a record number of 481.547 responses to the public consultation of new net neutrality rules in the summer of 2016 (BEREC, 2016). Similarly, FCC, the US regulator, received 3.7 million responses to its public consultation in 2015 [1].

Given the complexity of the topic, and arguably in part due to the lack of sound economic analysis, the resulting regulation mandates a case-by-case treatment of zero-rating programs both in the US and the EU. Moreover, zero-rating is cited as one of the driving forces of the proposed AT&T - Time Warner merger[2], thus its evaluation will be crucial for **competition authorities** as well. Despite its policy relevance and the general public's revealed interest in the matter, almost no rigorous economic analysis has been conducted about zero-rating.

In order to illustrate the rich variety of zero-rating programs and the various trade-offs they present, I will first provide some examples of current zero-rating programs in developed countries. I will then review related literature. Section 2 presents the set-up of the model. Section 3 presents the main results of the paper. Section 4 provides a welfare analysis of zero-rating programs. Section 5 concludes by discussing some of the assumptions and identifies several avenues of future research.

[1] http://www.npr.org/sections/alltechconsidered/2014/09/17/349243335/3-7-million-comments-later-heres-where-net-neutrality-stands

[2] http://www.ipwatchdog.com/2016/11/09/att-time-warner-merger-fcc-rulemaking-zero-rating-practices/id=74485

1.1 Typology of current zero-rating programs

In this section I will illustrate the different types of zero-rating agreements by describing some typical examples from the US and Belgium, for a recent review of zero-rating programs around the world from December 2016, see Yoo (2016).

The most prominent example of what I call an **open zero-rating program** is T-Mobile US's Binge On offer. Any video streaming service fulfilling T-Mobile's technical requirements can join the Binge On program and as a consequence getting zero-rated. Surprisingly, admission to Binge On is free for all CPs. Notice that I will use the terminology "open program" to highlight that any CP can join it, I do not require the admission to be free. Thanks to the permissive policy, more than 100 video providers are already part of the program, including the largest ones (Netflix, Youtube, Amazon Video) and even their competitors' services (go90, DirecTV).

I distinguish open programs from **exclusionary zero-rating programs**. US mobile carriers AT&T and Verizon provide good examples of such offers. AT&T zero-rates its own DirecTV app under its Sponsored Data program, and Verizon zero-rates its subsidiary, a video provider called go90. Although both AT&T and Verizon claim that any video provider could join the program in exchange of payment, these fees are not public. Moreover, the programs have been offered for months and no outside CP has joined them, so they are de facto exlusionary. FCC's action against them in December 2016 indicates that the regulatory body is worried about the offers' exclusiveness as well as the vertical integration involved. Finally, note that zero-rating is widespread in the EU as well, one example from Belgium is Proximus, whose customers can choose one out of 6 social media apps not to count against their data caps.

1.2 Related literature

To date, the study of zero-rating has been relegated to the realms of Law and Information Technology. For two recent summaries providing an overview of zero-rating programs and the current state of regulation, see Marsden (2016) and Yoo (2016). The FCC's and BEREC's public consultations gave rise to numerous advocacy papers discussing either the merits or the drawbacks of zero-rating programs, for instance Eisenach (2015), the ITIF report by Blake (2016) and the WWW Foundation's report by Drossos (2015). For a rather impartial overview of the main arguments, see CDT's report by Stallman and Adams (2016). Arguably the most comprehensive set of arguments against zero-rating are presented by van Schewick (2016), while the most comprehensive (informal) economic presentation of its merits is by Rogerson (2016).

Apart from my on-going work presented in the next section, a working paper from Jullien and Sand-Zantman (2016) has been the only attempt to model zero-rating in a formal economic setting. In this model, zero-rating is a tool for CPs to overcome the problem of the missing price on the market. Specifically, it views zero-rating as the modern equivalent of a toll-free number, an efficient way to give a discount to users who otherwise do not directly pay CPs. It shows that such a departure from net neutrality can be welfare improving. This model differs from my research project in several key aspects. Firstly, I aim to **model congestion more directly**, by explicitly modeling the ISP's capacity constraint and users' data caps. Moreover, my model will also be suitable to explain the emergence and co-existence of **different types of zero-rating programs** which seems to be a crucial factor in real-world examples.

I model the mobile internet market as a **two-sided platform**. The end users and the CPs are on the two sides of the market, intermediated by the ISPs. The CPs advertising revenue depends on the number of end users they capture, which gives rise to indirect network effects. For a survey of the literature, see Rysman (2009). Some more recent contributions to this topic include Belleflamme and Toulemonde (2009), Belleflamme and Peitz (2010), and Athey, Calvano, and Gans (2016).

Also closely related to my research project is the rich body of literature in theoretical industrial organization about **net neutrality**. With some notable exceptions (see e.g., Broos and Gautier (2015)) these articles have focused on the effect of **paid prioritization**. Paid prioritization is a business practice involving an ISP granting faster access for users of a content provider's data in exchange of a monetary payment. Allowing such an agreement could create the emergence of "fast-lanes" and "slow-lanes", clearly violating the principle of net neutrality. For a survey of paid prioritization, see Greenstein et al. (2016) or Krämer et al. (2013). Some recent research about the topic includes Bourreau et al. (2015); Choi et al. (2015); Peitz and Schuett (2016); and Reggiani and Valletti (2016).

At this point, I would like to stress that paid prioritization is substantially different from zero-rating in that it discriminates CPs' data along the dimension of *speed*, as opposed to the *price* dimension of zero-rating. If a consumer potentially reaches her monthly data cap, zero-rated content becomes free for her while all other content becomes costly. In the context of paid prioritization, users pay the same price but can access the content at different speeds. Conversely, in the context of zero-rating, users pay different prices for different content but the speed is homogenous.

In addition to the aspects mentioned above, my research project is naturally related to the vast literature of **pricing in the telecommunication industry** in general (see e.g., Laffont and Tirole (1994) and Laffont et al.(1998)), and the use of **three-part tariffs** in particular (e.g., Ascarza, Lambrecht, and Vilcassim (2012) and Chao (2013)). Three-part tariffs consist of a monthly fee, a usage allowance under which each unit of consumption is free, and an overage charge paid over the allowance. The connection is that I explicitly model data caps which can be seen as usage allowances, although I make the simplifying assumption that the overage charge is prohibitively high.

2 Setting

To study zero-rating, I model mobile internet as a two-sided market. A monopolistic internet service provider (ISP) acts as a two-sided platform connecting end users to content providers (CPs).

2.1 Content providers

There are three competing CPs: V_A and V_B are video streaming services which are potentially zero-rated by the ISPs. O denotes all other content that is never zero-rated. The VPs' revenue come from advertising, they derive profits a and b for every gigabyte an end user downloads from their content. Without loss of generality, I normalize $b = 1$ and assume $a \geq 1$ thus V_A is the stronger firm. They might pay to get zero-rated by the ISP. For simplicity, I assume that end users perceive V_A and V_B's content as identical so the only potential difference between them is in their revenue generating ability. Therefore end users split their demand equally between the two VPs whenever both are zero-rated or none of them are.

2.2 Internet service provider

The monopolistic mobile carrier is modeled as a last-mile ISP connecting end users to the CPs. This ISP charges a fixed monthly subscription fee, F, to end users. The ISP's network has a total capacity Q. This means that if the total amount of content end users demand is larger than Q then the mobile carrier wil not be able to serve all of them. The rationing rule is described in the next section.

Assume that the ISP can only charge a CP for content delivery if they enter into a zero-rating agreement. This corresponds to the case of a last-mile ISP whenever paid prioritization is banned. The monopoly has three options. Firstly, it can decide not to zero-rate any content. In this case its only revenue comes from the end users. Secondly, it can offer an exclusive contract (potentially in exchange of a fee) to one of the CPs, guaranteeing that it only zero-rates the content of that CP. Thirdly, it can offer an open ZR agreement where both CPs can join the zero-rating program for a fee. For simplicity, assume that the ISP has all the bargaining power and can act as a mechanism designer in offering zero-rating arrangements.

2.3 End users

N homogenous end users simultaneously decide about their consumption of different types of content given two constraints. Let v_{iA}, v_{iB}, o_i denote user i's consumption (measured in gigabytes) of service providers V_A, V_B and O, respectively. Firstly, the total amount of non-zero-rated data a consumer uses up cannot exceed the data cap K:

$$\delta_A v_{iA} + \delta_B v_{iB} + o_i \leq K \quad \text{for all } i \in \{1, 2, ..N\},$$

where $\delta_A = 0$ if V_A's content is zero-rated, and $\delta_A = 1$ otherwise. Thus δ_A captures the ISP's zero-rating decision of excluding data generated by V_A from the data cap. The definition of δ_B is analogous.

Secondly, there is a maximal amount of time end users can/want to spend on browsing the internet, which translates to B gigabytes of data. I will refer to this quantity B as the end users' bliss point.

$$v_{iA} + v_{iB} + o_i \leq B \quad \text{for all } i \in \{1, 2, ..N\},$$

For simplicity, assume that V_A and V_B are perfect substitutes, moreover, users have Cobb-Douglas preferences between video and other content.

Consumers are rational in the sense that they anticipate the potential congestion effect that their consumption could cause. In particular, if total consumption exceeds the ISP's capacity constraint, i.e., if

$$\sum_i (v_{iA} + v_{iB} + o_i) > Q$$

then some consumers will not be served and get 0 utility. I assume random rationing, i.e., the probability of getting served equals

$$P_i \equiv P \equiv \min\{\frac{Q}{\sum_{i=1}^{N}(v_{iA}+v_{iB}+o_i)};\ 1\}$$

for each consumer. Note that random rationing is a natural assumption given that consumers are homogeneous and paid prioritization of content is banned. Thus the end users' maximization program is

$$\max_{v_{iA},v_{iB},o_i} \quad P(v_{iA},v_{iB},o_i)\left((v_{iA}+v_{iB})^{\alpha}o_i^{1-\alpha}-F\right) \qquad \text{s.t.}$$
$$\delta_A v_{iA}+\delta_B v_{iB}+o_i \le K$$
$$v_{iA}+v_{iB}+o_i \le B.$$

Assume $0<\alpha\le 1$ so that users value video content, and assume $B>K$, otherwise the data cap would never bind. Assume

$$NK = Q < NB,$$

i.e., the ISP's capacity is exactly sufficient to serve all N consumers up to their data cap K, but insufficient to serve consumers if they all decide to consume up to their bliss point B.

2.4 Timing

The timing of the game is the following:

1. ISP makes take-it-or-leave-it zero-rating offers to 0, 1 or 2 CPs.
2. CPs simultaneously and independently decide to accept or reject the offer .
3. End users simultaneously and independently maximize their expected net utility.

All players are rational and the description of the game is common knowledge among them. As I assume the ISP having all the bargaining power, it is natural for it to start the game. Moreover, it is also realistic to assume that end users make their consumption decisions after having observed which contents are zero-rated.

3 Results

I solve the game by backwards induction, starting with end users' consumption decisions given the zero-rating regime they face.

3.1 End user's choice

All N end users maximize their expected net utility simultaneously and independently given the two constraints they face. Lemma 1 highlights the most interesting result of these individual maximization decisions.

Lemma 1. *Whenever $\alpha > \frac{1}{N}\frac{B-K}{B}$ holds, rational consumers do not internalize the congestion externality, i.e. they consume up to their bliss point B when at least one VP is zero-rated.*

This is a classical multiplayer prisoners' dilemma or tragedy of the commons situation. Although end users are aware that a high consumption level leads to them being served with a lower probability, the individual gain from large consumption outweighs this congestion effect. From now on, assume

$$\alpha > \frac{1}{N}\frac{B-K}{B} \equiv \underline{\alpha}.$$

On the one hand, $\underline{\alpha} < \frac{1}{N}$, i.e., it is a very small value for large N and ISPs typically have tens of thousands of costumers, so this assumption only excludes extremely unattractive video content. On the other hand, no closed form solution exists to determine the users' optimal consumption levels for even smaller values of α.

Table 1 summarizes end users' consumption decisions. Note that the two VPs being perfect substitutes, end users derive the same utility consuming their content. Thus their overall video consumption is the same whether one or two VPs are zero-rated. Hence "ZR" in the following table stands for at least one VP being zero-rated, and it shows the total video consumption per user, $v_{iA} + v_{iB}$. Whenever one VP is exclusively zero-rated, it gets the total video demand, the other gets 0. When both or none are zero-rated, they each get half of this value. Define the following threshold value of α:

$$\overline{\alpha} \equiv 1 - \frac{K}{B}.$$

Table 1: End users' optimal consumption decisions

	$v_{iA} + v_{iB}$	o_i	Aggregate demand
NO ZR	αK	$(1-\alpha)K$	NK (= Q)
ZR with $\alpha < \overline{\alpha}$	$B - K$	K	NB (> Q)
ZR with $\alpha \geq \overline{\alpha}$	αB	$(1-\alpha)B$	NB (> Q)

The first line of Table 1 indicates that in the absence of zero-rating end users divide their data allowance proportionally to the attractiveness of content, which is the standard result given their Cobb-Douglas preferences.

From Table 1, it is clear that $\overline{\alpha}$ plays a crucial role in delimiting unattractive and attractive video content. I call content unattractive when $\alpha < \overline{\alpha}$ and attractive when $\alpha \geq \overline{\alpha}$.

The second line of the table shows users' consumption decisions when at least one VP is zero-rated but video content is unattractive. In this case other content, o, is so attractive that end users would want to consume more of it than their data cap K would allow, so they spend all their allowance on other content, i.e., $o_i = K$. Even though unattractive, given the tragedy of the commons situation, they still consume as much video as they can, which is exactly $B-K$.

The third line shows the case of attractive video content being zero-rated. When video content is attractive, dividing their total "budget", in this case their bliss point B proportional to attractiveness of content is optimal. Indeed, attractive video content means that other content is relatively unattractive, so $(1-\alpha)B < K$, i.e., users do not hit their data cap while consuming other content.

Finally, the last column of Table 1 shows the aggregate demand of all end users for all content. Clearly, the ISP can only serve all consumers when no zero-rating program is in place, otherwise they all consume up to their bliss point thus the ISP has to ration consumers.

3.2 ISP's choice

The mobile carrier ISP acts as a mechanism designer by offering zero-rating programs to the CPs. It chooses the zero-rating regime that maximizes its profit while correctly anticipating the acceptance decisions of the CPs. It is worth distinguishing two cases: the case of unattractive content and the case of attractive content.

Case of unattractive content $(\alpha < \overline{\alpha})$:

If the ISP offers a ZR program with participation fee z when content is unattractive, then the following game is played by the two VPs:

Table 2: VPs' choice when content is unattractive

		V_B: Decline	V_B: Accept
V_A	Decline	$Qa\alpha/2$,$Q\alpha/2$	0,$Q\overline{\alpha} - z$
V_A	Accept	$Qa\overline{\alpha} - z$,0	$Qa\overline{\alpha}/2 - z$,$Q\overline{\alpha}/2 - z$

I show in the Appendix that by setting $z = (\overline{\alpha}/2)Q$ the ISP can create a prisoners' dilemma situation where both VPs accept to pay the fee. Moreover, this is the highest fee that both VPs are willing to accept. Therefore its optimal revenue from the VPs under an open ZR program equals double this fee, i.e., $\overline{\alpha}Q$.

I also show that the exclusionary offer granting the ISP with the highest revenue is to the stronger firm. The fee for exclusionary zero-rating equals $(\overline{\alpha} - \alpha/2)Qa$. Intuitively, approaching the stronger VP is more valuable than approaching the weaker VP as the stronger firm's revenue is always $a > geq1$ times larger, thus the ISP can extract a times more revenue from it.

Notice that there is a trade-off for the ISP: it can extract a lower fee from both VPs with an open zero-rating program or extract a higher fee by offering exclusivity to the stronger firm. Hence the mobile carrier chooses the open zero-rating if and only if

$$\overline{\alpha}Q \geq (\overline{\alpha} - \alpha/2)Qa \;\Leftrightarrow\; \frac{2(a-1)}{a}\overline{\alpha} \leq \alpha (< \overline{\alpha}),$$

i.e., exclusive zero-rating is only offered if the content is very unattractive. Intuitively, the more unattractive their content is, the more VPs can gain from being zero-rated, because otherwise their demand would be very low.

Notice that this condition translates to $0 \leq \alpha$ in the extreme case of perfectly symmetric firms, therefore exclusive zero-rating programs are dominated if the VPs' revenue generating ability coincides.

The ISP faces the following trade-off: compared to the case of the absence of zero-rating, offering a zero-rating program reduces its revenue from the end user side while increases its profit by collecting participation fee(s).

Denote R^* the optimal revenue of the ISP from an open or exclusive zero-rating program, i.e.,

$$R^* = \max\left(\overline{\alpha}Q \;;\; (\overline{\alpha} - \alpha/2)Qa\right).$$

The ISP thus implements a zero-rating program as opposed to no zero-rating whenever

$$R^* + \frac{Q}{B}F \geq \frac{Q}{K}F \;\Leftrightarrow\; F \leq \max\left(K \;;\; a(K - \alpha\frac{KB}{2(B-K)})\right),$$

i.e., zero-rating is more likely if

- F is small,
- a is large,
- α is low, i.e., the zero-rated content is less attractive.

Given the trade-off described above, it is not surprising that zero-rating is more likely to be offered when advertising revenue from the CPs' side (a) is large, and whenever revenue from the end user side (subscription fee F) is small.

However, it is more surprising that zero-rating is more likely to occur when content is less attractive. Intuitively, the less attractive the content is, the more VPs can gain from being zero-rated because zero-rating their content results in a large jump in demand and consequently in revenue. The ISP, using its large bargaining power, can extract some of the increase in revenue from the VP, thus it finds it more profitable to approach CPs if their content is unattractive.

Case of attractive content ($\alpha \geq \overline{\alpha}$) :

If the ISP offers a ZR program with participation fee z when content is attractive, then the following game is played by the two VPs:

Table 3: VPs' choice when content is attractive

		V_B Decline	V_B Accept
V_A	Decline	$Qa\alpha/2$,$Q\alpha/2$	0,$Q\alpha - z$
	Accept	$Qa\alpha - z$,0	$Qa\alpha/2 - z$,$Q\alpha/2 - z$

This case is simpler than the case of unattractive content because demand and revenue of CPs is proportional to α both with and without zero-rating. Similarly tot he previous case, I show that $z = Q\alpha/2$ creates a prisoners' dilemma situation where both VPs accept the offer. Thus the ISP's maximal revenue from an open zero-rating program is $Q\alpha$. Moreover, I show in the Appendix that its best strategy involving exclusive zero-rating is to offer it to the stronger firm, and the ISP's optimal revenue is then $Qa\alpha/2$.

Therefore the ISP prefers offering an open zero-rating program if and only if $a < 2$, i.e., the two VPs are relatively similar. Furthermore, the ISP implements some kind of zero-rating program as opposed to no zero-rating whenever

$$F \leq \frac{KB}{B-K} \max \left(\alpha \ ; \ a\alpha/2 \right)$$

i.e., zero-rating is more likely if

- F is small,
- a is large,
- α is large, i.e., the zero-rated content is more attractive.

The first two of these comparative statics result coincide with the results in case of unattractive content. However, contrary to the previous case, if video content is over the threshold of attractiveness then zero-rating will more likely be offered by the ISP as content the attractiveness of the content increases. Intuitively, in this case VPs' demand and revenue is proportional to the attractiveness, so the more attractive the content, the larger revenue the ISP can extract from the VPs.

The following proposition summarizes the results.

Proposition 1. .

- *An open zero-rating program is implemented if either (i)* $\frac{2(a-1)}{a}\overline{\alpha} \leq \alpha < \overline{\alpha}$ *and* $F < K$ *or (ii)* $\alpha \geq \overline{\alpha}$ *and* $F < \alpha\frac{KB}{B-K}$ *and* $a < 2$ *is satisfied.*
- *The stronger VP's content is exclusively zero-rated if either (i)* $\alpha < \frac{2(a-1)}{a}\overline{\alpha}$ *and* $F < a(K - \alpha\frac{KB}{2(B-K)})$ *or (ii)* $\alpha \geq \overline{\alpha}$ *and* $F < \alpha\frac{a}{2}\frac{KB}{(B-K)}$ *and* $a \geq 2$ *is satisfied.*
- *No zero-rating arrangements are implemented otherwise.*

The next corollary highlights the most unusual aspect of the results.

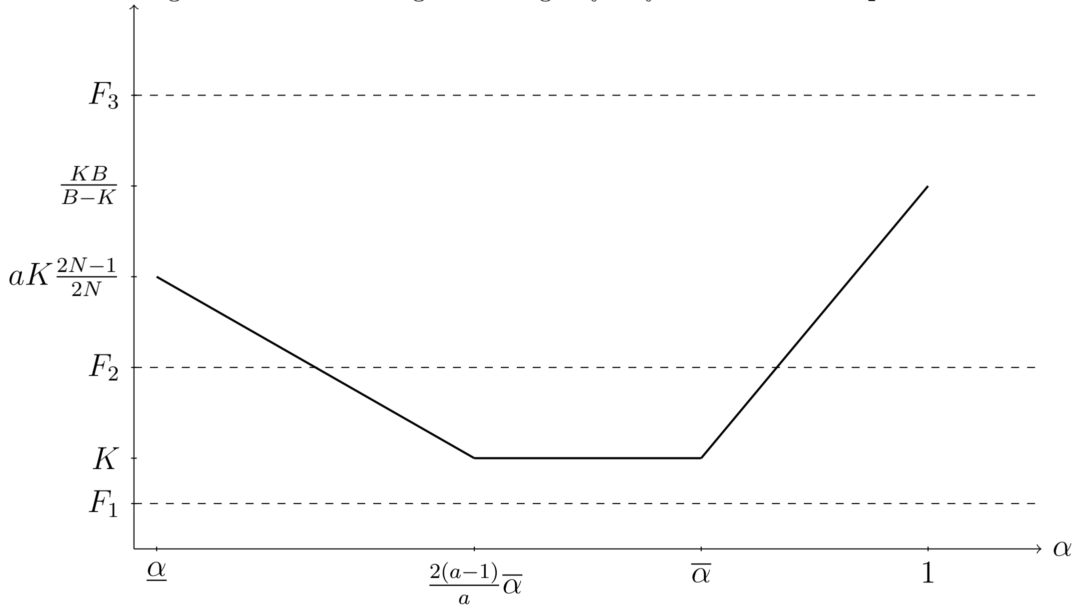
Corollary 1. *There exists levels of attractiveness where the likelihood of the content being zero-rating increases as the attractiveness of content decreases whenever video providers' revenue generating ability is different, i.e.,* $a > \frac{2N}{2N-1}$ *and the content is sufficiently unattractive.*

To better illustrate these results, the next section provides graphical examples of the conditions of implementing different types of zero-rating programs.

3.3 Implementation of zero-rating programs

In this section I study two different cases depending on the asymmetry of video providers' ability to generate advertising revenue. Figure 1 depicts the case of slight asymmetry, when $1 < a < 2$.

Figure 1: Zero-rating with slightly asymmetric video providers



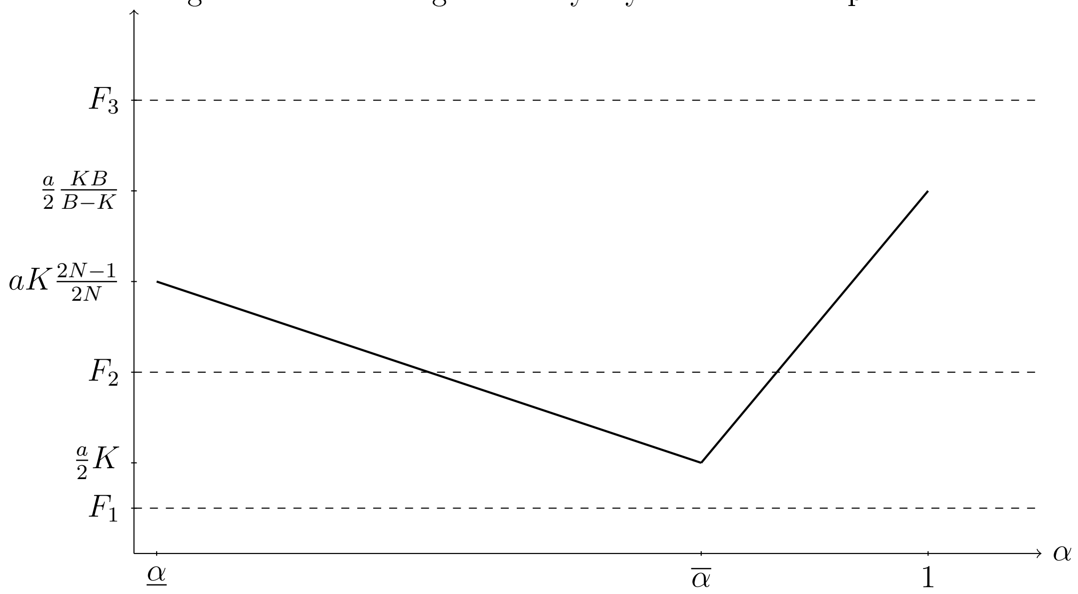
The thick lines in Figure 1 represent the threshold value of subscription fee F as a function of the attractiveness of content, α. For any α if F is below the line then the mobile carrier zero-rates at least one video provider, otherwise it does not. The decreasing part of the line corresponds to an exclusive zero-rating arrangement between the ISP and the stronger video provider, whereas the constant and the increasing lines correspond to open zero-rating programs.

Consider three different values of F as depicted with dashed horizontal lines in Figure 1. Firstly, if the subscription fee is very small, as in the case of F_1 then at least one VP will get zero-rated independently of the attractiveness of content. Conversely, if the subscription fee is very large, e.g., F_3, then no zero-rating will be offered by the ISP. Finally, arguably the most interesting case is the one of an intermediary level of subscription fees, as in F_2. In such a case, only very unattractive and attractive content will be zero-rated, the former by an exclusionary contract, whereas the latter by an open program. The existence of such levels of F are guaranteed by Corollary 1.

Figure 2 depicts the case of very asymmetric video providers when $a \geq 2$. The main difference with respect to the previous case is that exclusive zero-rating programs are always more profitable for the ISP than open zero-rating programs. Intuitively, the stonger video provider being so lucrative, the mobile carrier would lose too much by charging a sufficiently low fee that would be acceptable to the weaker firm. As a result, the graph is simpler, the the flat part of the threshold disappears.

However, the same qualitative insight holds: there are subscription fee levels, such as F_2 in Figure 2, under which only very unattractive and attractive content gets zero-rated, intermediary content does not.

Figure 2: Zero-rating with very asymmetric video providers



4 Social welfare

In this model, consumer surplus can be defined as the sum of net utility of the consumers served. Moreover, social welfare can be defined as the sum of gross utility of consumers served and the three CPs' joint advertising revenue. Note that these utilitarian values are the standard definitions used in the literature, however, in the context of rationing they seem to be quite restrictive.

The sum of end users' gross utility equals

$$Q\alpha^{\alpha}(1-\alpha)^{1-\alpha}$$

for $\alpha \geq \overline{\alpha}$ independently of the zero-rating regime and also in the absence of zero-rating for $\alpha < \overline{\alpha}$. However, in the Appendix I show that for unattractive content ($\alpha < \overline{\alpha}$), under zero-rating the sum of gross utility is always lower than this level and equals:

$$\frac{Q}{B}(B-K)^{\alpha}K^{1-\alpha}.$$

Moreover, in the Appendix I show that the loss in welfare is increasing in

B/K (i.e., in congestion). Intuitively, the negative externality end users exert on each other reduces their aggregate gross utility whenever the zero-rated content is unattractive. However, zero-rating has a positive impact on social welfare as well: it reallocates demand to the stronger firm, generating more overall profit. This reallocation effect disappears when the two VPs are symmetric ($a = 1$) and its size increases in a. Given that the size of congestion externality is independent of the level of asymmetry of VPs, there exists a threshold level $\widehat{a}$ where the two effects cancel out.

Therefore zero-rating attractive content is always beneficial both to consumers and social welfare. Indeed, end users' gross utility is unchanged whereas fewer of them has to pay the subscription fee, in addition, the reallocation effect increases CPs overall profit.

Proposition 2 summarizes the results.

Proposition 2. *If the video providers' content is attractive, i.e., $\alpha \geq \overline{\alpha}$, a zero-rating program strictly increases both consumer surplus and social welfare. If content is unattractive and the VPs' revenue generating ability is not very different, i.e., $\alpha < \overline{\alpha}$ and $a < \widehat{a}$, social welfare strictly decreases if a zero-rating program is implemented.*

5 Discussion

In the future, I plan to explore more in depth the two-sided nature of the mobile internet market. In the current model, the ISP has only a crude instrument to take advantage of the indirect externalities. In particular, by offering an exclusionary or an open program, on the one hand it reduces its revenue from the user-side, on the other hand zero-rating allows it to extract revenue from the CP-side. Although the ISP has complete freedom in the design of its zero-rating offers to CPs, it has limited ability to influence the user side of the market. Thus relaxing the fixed subscription fee assumption, either by letting the ISP choose it endogenously or by assuming a potentially heterogeneous outside option for users, would amplify the trade-offs caused by cross-group network effects. Therefore, making the model more realistic in this aspect would potentially reveal important insights that would otherwise be hidden by the crudeness of the ISP's instruments on the user side.

Next, I plan to investigate the ISP's investment incentives by letting it choose its capacity constraint Q endogenously. A large part of the literature on paid prioritization has analyzed ISPs' investment decisions as it is one of the ISPs' main justification for deviating from net neutrality. A similar analysis could be conducted in the context of zero-rating. Indeed, mobile carriers invest huge sums of money every year to expand their infrastructure, both by updating their devices to be compatible with new standards (transition from 3G to 4G to 5G networks) and by bidding in spectrum auctions. My model will be suitable to provide answers about the effects of zero-rating regulation. In particular, do revenues accrued from zero-rating help the ISP expand its capacity, or on the contrary, would zero-rating provide perverse incentives for the ISP to withhold building new capacity? Opponents claim that the latter scenario is a real threat, the ISP would hold its capacity and data caps artificially low in order to make zero-rating more profitable for CPs and thus extract more surplus from them.

Finally, I also plan to compare different forms of regulation of zero-rated services. Several levels of regulation are feasible. The harshest regulation would completely ban all kind of zero-rating (i.e., both exclusionary and open programs). A somewhat more permissive form of regulation would consist of banning exclusionary programs while allowing open programs. An even lighter form of regulation would be to ban exclusionary contracts with CPs that are the ISPs' own subsidiaries (recent action of the FCC against AT&T and Verizon in December 2016 points toward this being the US regulator's current approach[3]). Finally, all these forms of regulation should be compared to the laissez-faire approach (which seems to be the incoming Trump administration's preferred strategy[4]).

Appendix

Proof of Proposition 1

In order to prove Proposition 1, firstly notice that the data cap will bind by the assumption ($K < B$) whenever no zero-rating program is implemented. Therefore the end users' maximization program simplifies to a standard Cobb-Douglas utility maximization with budget constraint K. This leads directly to the results presented in the first line of Table 1.

Next, in order to derive the result of Lemma 1 and more generally, end users' consumption decisions under zero-rating (as described in Table 1), the representative end user solves their maximization program described in the main text. The objective function for deriving the Karush-Kuhn-Tucker conditions writes as

[3] https://cdn.arstechnica.net/wp-content/uploads/2016/12/Letter-to-R.-Quinn-12.1.16.pdf
[4] https://www.competitionpolicyinternational.com/us-trump-appoints-two-anti-net-neutrality-advocates-for-fcc-transition/

$$
\begin{aligned}
L(v_{iA}, v_{iB}, o_i, \lambda_1, \lambda_2) = & P(v_{iA}, v_{iB}, o_i)\left((v_{iA}+v_{iB})^{\alpha} o_i^{1-\alpha} - F\right) - \\
& \lambda_1\left[\delta_A v_{iA} + \delta_B v_{iB} + o_i - K\right] - \lambda_2\left[v_{iA}+v_{iB}+o_i-B\right]
\end{aligned}
$$

The solution of this program provides the results described in Table 1 and Lemma 1.

Next, I derive the ISP's optimal choice of zero-rating regime for unattractive content. The ISP chooses z and thus the zero-rating regime that generates the highest revenue given that the VPs play the game described in Table 2. Consider the following inequalities:

- $Qa(\overline{\alpha} - \alpha/2) \geq Q(\overline{\alpha} - \alpha/2)$ as $a \geq 1$,
- $Qa(\overline{\alpha} - \alpha/2) \geq Qa\overline{\alpha}/2 \geq Q\overline{\alpha}/2$ as $\overline{\alpha} \geq \alpha$ and $a \geq 1$.

Thus it is straightforward that if the ISP chooses

- $z > Qa(\overline{\alpha} - \alpha/2)$ then the equilibrium strategy of VPs is (Decline,Decline) thus the ISP's revenue is 0,
- $Q\overline{\alpha}/2 < z \leq Qa(\overline{\alpha} - \alpha/2)$ then the equilibrium strategy of VPs is (Accept,Decline) thus the ISP's revenue is z,
- $z \leq Q\overline{\alpha}/2$ then the equilibrium strategy of VPs is (Accept,Accept) thus the ISP's revenue is $2z$.

Therefore it is clear that the ISP will choose among two options: have a revenue of $Qa(\overline{\alpha} - \alpha/2)$ by exclusively zero-rating the stronger firm, or have a revenue of $2Q\overline{\alpha}/2$ by offering a fee of $Q\overline{\alpha}/2$ that leads to an open zero-rating program.

Next, I derive the ISP's optimal choice of zero-rating regime for attractive content. It is simpler than the case of unattractive content, the sole inequality to consider is $Qa\alpha/2 \geq Q\alpha/2$ which always holds as $a \geq 1$. Thus it is straightforward that if the ISP chooses

- $z > Qa\alpha/2$ then the equilibrium strategy of VPs is (Decline,Decline) thus the ISP's revenue is 0,
- $Q\alpha/2 < z \leq Qa\alpha/2$ then the equilibrium strategy of VPs is (Accept,Decline) thus the ISP's revenue is z,

- $z \leq Q\alpha/2$ then the equilibrium strategy of VPs is (Accept,Accept) thus the ISP's revenue is $2z$.

Therefore it is clear that the ISP will choose among two options: have a revenue of $Qa\alpha/2$ by exclusively zero-rating the stronger firm, or have a revenue of $2Q\alpha/2$ by offering a fee of $Q\alpha/2$ that leads to an open zero-rating program. $\square$

Proof of Proposition 2

First I show that

$$\alpha^\alpha(1-\alpha)^{1-\alpha} > \frac{1}{B}(B-K)^\alpha K^{1-\alpha}$$

for $\alpha < \overline{\alpha}$. To prove this, let $g(x) = x^\alpha(1-x)^{1-\alpha}$. Note that

$$g'(x) = x^{\alpha-1}(1-x)^{-\alpha}(\alpha - x)$$

$$g''(x) = -\alpha(1-\alpha)x^{\alpha-2}(1-x)^{-\alpha-1} < 0,$$

so g is a strictly concave function that attains its maximum at α. Using this notation, the right-hand side of the inequality to be proven rewrites as

$$\left(\frac{B-K}{B}\right)^\alpha \left(\frac{K}{B}\right)^{1-\alpha} = \overline{\alpha}^\alpha(1-\overline{\alpha})^{1-\alpha} = g(\overline{\alpha}).$$

Therefore the inequality to be proven simplifies to $g(\alpha) > g(\overline{\alpha})$ for $\alpha < \overline{\alpha}$. This is straightforward given that g is maximal at α. From this formulation, it also follows that the difference between the two sides of the equation grows as $\overline{\alpha}$ grows, thus the loss in welfare is indeed increasing in B/K, i.e., in congestion. $\square$

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