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Abstract

This study examines zero-rating (ZR), a commercial method implemented by Internet service providers (ISPs) that treat particular content providers' (CPs) data as free content. In this study, a model is constructed in which an end-user uses content from two CPs within a data cap, and the ISP chooses an optimal ZR plan which maximizes its profit. We show that the ISP zero-rates one or both CPs in equilibrium depending on (1) the ISP's marginal cost to deliver content, (2) the difference between the quality of the content provided by the two CPs, and (3) the two CPs' advertising power. We demonstrate that an increase in the ISP's marginal cost makes it more likely that a ZR plan resulting in heavy traffic will be implemented, and an increase in the difference between the content quality makes it less likely that a ZR plan in favor of the higher quality CP will be implemented.

Keywords: Mobile Internet; Zero-rating; Sponsored-data; Net Neutrality; Vertical integration

JEL Classification: D21; L11; L96

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1 Introduction

ZR[1] is a commercial method implemented by ISPs, and, in particular, it is frequently implemented by mobile ISPs. Many mobile ISPs set monthly data caps, which are the monthly upper bounds of usage volumes that are available for their end-users. By setting data caps, ISPs exercise second degree price discrimination and alleviate traffic congestion (Economides and Hermalin, 2015). ZR plans (or Sponsored data plans [2]) specify particular content providers' (CPs') data as free contents; end-users can use these zero-rated CPs' contents as much as they like without additional payment.

In Japan today, some MNOs and mobile virtual network operators offer their own ZR plans. For example, subscribers of SoftBank, the third-largest MNO, have unlimited free access to YouTube videos and Facebook.[3] Although similar data plans are offered by ISPs globally, there is a debate as to whether or not ZR plans violate the principle of "net neutrality." The term "net neutrality" does not have widely accepted definition, but means that ISPs do not favor particular content or do not charge content providers for delivering contents.[4] There are many papers that deal with net neutrality and argue the trade-off between fairness and effectiveness of markets (Krämer et al., 2013).[5]

Although ZR plans are accepted by end-users, there are opponents of ZR who claim that such plans may distort the competition among CPs because they give an advantage to those CPs whose contents are zero-rated. Regulators of each country have adopted a stance on ZR; some regard ZR as illegal, whereas others have adopted a wait-and-see attitude (Marsden, 2016; Yoo, 2017). Therefore, to facilitate policy making, we would like to answer the question of which types of CPs are more likely to be zero-rated. Moreover, we investigate how the ISP's cost and CPs' advertising power affect the ISP's zero-rating choice.

In this study, we analyze an ISP's ZR choice when there is a monopolistic ISP and two CPs in the market. In this model, the ISP can select one of the following ZR plans: (i) exclusive ZR with CP_1, (ii) exclusive ZR with CP_2, or (iii) ZR with both CPs (open ZR).

[1] abbreviations: CP = content provider, ISP = internet service provider, MNO = mobile network operator, ZR = zero-rating

[2] A ZR plan is sometimes called a "Sponsored data plan" when ISPs receive monetary compensation from zero-rated CPs. In this study, we focus on sponsored data plans, but because we do not have to distinguish such plans from 'non-sponsored' ZR plans, hereafter we use the term ZR plans.

[3] https://www.softbank.jp/en/mobile/price_plan/data/merihari-plan/

[4] The term "net neutrality" was coined by Wu (2003), and see, for example, Hahn and Wallsten (2006) for some debates about "net neutrality."

[5] The current situation regarding zero-rating in Japan is summarized by Jitsuzumi (2018).

We assume that the two CPs differ only in the quality of their content; CP_1's content is higher than CP_2's.

In order to simplify the model and derive meaningful results, we introduce some assumptions. First, we assume the ISP can not reset the subscription price and the data cap of its data plan when it introduces the optimal zero-rating plan. This assumption is realistic because the ISP usually introduces ZR services into existing data plans whose prices and data caps have taken root in the market.[6] Second, we assume the ISP offers single data plan and it does not contain an overage fee, which is paid by end-users who want to use online contents over the data cap. We mainly focus on the ISP's ZR choice and do not focus on how the ISP extract end-users' surplus. Therefore we adopt the representative end-user model and consider the single data-plan.

In such framework, we show that the ISP chooses any of the three ZR plans in equilibrium depending on (1) the ISP's marginal cost to deliver contents, (2) the difference between the quality of the content provided by the two CPs, and (3) the CPs' advertising power. In this model, I assume that the ISP's profit from consumers is fixed. Therefore, the ISP's ZR choice is depending only on the ZR revenue which is equal to ZR fee from CPs, and the increase in the ISP's delivery cost. The above three factors affects the ISP's choice through these two. In particular, the ISP's marginal cost plays an important role in determining the resulting consumption levels under each ZR plan. If the ISP's cost is low, the ISP presets a sufficiently large data cap, thus exclusive ZRs may lead to consumption levels similar to open ZR. Therefore, the ISP's cost and the size of the data cap are important factors when we debate the unfairness of ZR plans. This study provides a model which analyzes the ISP's ZR behavior with considering how the ISP's cost, the data cap and its ZR choice interact with each other.

Moreover, we conduct comparative analysis to examine the effects of the above factors on the ISP's choice. We demonstrate that an increase in the ISP's marginal cost makes it more likely that a ZR plan resulting in heavy traffic will be implemented, and that an increase in the difference between the content quality makes it less likely that a ZR plan in favor of the higher quality CP will be implemented. For social welfare, in equilibrium, the ISP's choice results in the amount of consumption which is less than or equal to the optimal level. This is because the ISP does not take the end-user's surplus and a part of the CPs' advertising revenue into account. At last of this paper, we also consider the

[6] An example of this case is 'Binge On' which was offered by T-Mobile. See https://www.t-mobile.com/offers/binge-on-streaming-video

case when the ISP is integrated with one CP. In such situation, the ISP zero-rates the unaffiliated CP to gain revenue from the ZR fee when the delivery cost is low. On the other hand, when the delivery cost is high, the integrated ISP balances the affiliated CP's profit and zero-rating fee from the unaffiliated CP, and implements exclusive ZR for the unaffiliated CP or Open ZR.

From the above results, we conclude that, in order to judge whether the competition between CPs is distorted or not, the size of the data cap is a important factor. Depending on the data cap, not-zero-rated CP may benefit from ZR. For social welfare, enabling the ISP to collect ZR fee from CPs is not sufficient to achieve socially optimal consumption level. The end-users may have to absorb an increase in the ISP's delivery cost to enjoy more online contents.

1.1 Related literature

The present study mainly relates to the strand of literature which discuss the effect of zero-rating on the ISPs' pricing, the competition between CPs, social welfare and so on. Most of them uses market models in which the ISP mediates between CPs and consumers, and collects fees from them.[7]

Jullien and Sand-Zantman (2018), Schnurr and Wiewiorra (2018), and Somogyi (2017) analyze markets where a monopolistic ISP receives subscription fees from end-users and ZR fees from CPs.[8] The three studies assume that the contents are free for end-users, and we follow these settings. Jullien and Sand-Zantman (2018) view contents as non-competing goods and end-users use all the contents. They demonstrate that the monopolistic ISP can use ZR to screen efficient CPs that have a high willingness to pay for traffic.

Our study adopts similar settings about the way to describe ZR to those of Schnurr and Wiewiorra (2018); the end-users can consume contents within data cap, and traffics for the zero-rated contents are not counted against the data cap. Schnurr and Wiewiorra (2018) distinguish sponsored data plans from ZR plans, and analyze how the ISP sets the subscription fee and data cap in each pricing scheme. They also assess optimal pricing schemes for the ISP and social welfare. In their model, the ISP always prefer ZR for the weaker CP to ZR for the stronger CP, because the ISP can extract more surplus from

[7]To the best of my knowledge, there are no studies which analyze ZR with indirect network effects between CPs and consumers, and our study also does not allow such effects. Introducing the network effects may be challenging because the ISP is usually assumed to adopt a complex pricing structure.

[8]Jullien and Sand-Zantman (2018) assume that the ISP also receives delivery fees from CPs.

consumers with ZR for the weaker CP.

Somogyi (2017) focuses on the ISP's ZR choice with traffic problem. He assumes that there are two video providers (VPs) in the market that may be zero-rated, and there are also other CPs that are never zero-rated. The author demonstrates that the ISP may zero-rate the stronger VP or both VPs when video contents are either very attractive or unattractive for end-users. Somogyi (2017) is the closest in spirit to ours; however, there are some differences. In Somogyi (2017), the two video contents are assumed to be perfect compatible goods, and therefore consumers do not take care about which ZR plans are implemented. Moreover, because the stronger VP can gain more advertising revenue and the ISP can extract it, the ISP always prefers ZR for the stronger VP to ZR for the weaker VP. In our model, we introduce the quality difference between two CPs to analyze the ISP's more complicated ZR choice.

Jeitschko et al. (2020) also use a monopolistic ISP model which is a platform between CPs and consumers, but they assume that CPs also can charge end-users for their contents. They particularly investigate ZRs which are offered by an integrated ISP and a CP. They find that regardless of whether monetary transfer is prohibited or not, vertical integration improves social welfare with ZR. There are also a few papers which assume an ISP can collect fees only from end-users. Gautier and Somogyi (2020) compares the ISP's two way of discriminating contents; the ISP can discriminate between two CPs in regards to delivery speed (Prioritization regime), or price for end-users (Zero-rating regime). Hoernig and Monteiro (2020) analyze the situation where one content has a network effect and demonstrate that the ISP zero-rates the content when its network effect is strong, although the ISP cannot receive a ZR fee.

Our paper is also related to the literature on input price discrimination, in particular, the papers study which type of downstream firm receives a discount from the upstream supplier. The supplier may charge higher input price for either more efficient downstream firm or less efficient firm, which depends on the demand system in the final good market. (See, for example, Li (2014) and Inderst and Shaffer (2009)).

The remainder of the paper is structured as follows. Section 2 introduces the model. In Section 3, we derive the ISP's equilibrium choices and resulting consumption and ZR fees. In Section 4, we examine the effect of some parameters on the ISP's choice. In Section 5, we conduct welfare analysis. Section 6 contains an extension in which the ISP is integrated with one of the two CPs, and Section 7 concludes.

2 Model

2.1 End-user

There is a representative end-user who subscribes to a data plan which is provided by a monopolistic ISP. The representative end-user can enjoy content 1 and content 2 with the data plan. His/her utility function from the two forms of content is

$$u = \gamma x_1 + x_2 - \frac{x_1^2 + x_1 x_2 + x_2^2}{2}, \tag{1}$$

where x_1 (x_2) represents the consumption of content 1 (2), and $\gamma > 1$. We refer to γ as a difference between the quality of the content provided by the two CPs. This is the only difference between the two contents.

2.2 Content providers

There are two content providers, CP_1 and CP_2, and each of them provides content 1 and content 2. The CPs earn revenue only from advertising. Their advertising revenue is $\pi_i = a_i n_i$, where a_i represents the advertising fee that is set by CP_i and n_i represents the number of advertisers that place advertisements on content i. Content providers face the following advertising market. In the advertising market, there are countless advertisers in the interval $[0, \infty)$ and the two CPs are located at point 0. The advertisers consider the effectiveness of advertisements they place on each content to be independent, and advertisers that are located at point d obtain utility

$$v_i = x_i - a_i - td, \tag{2}$$

from placing an advertisement on content $i = \{1, 2\}$ when the end-user's consumption is x_i and CP_i sets the advertising fee to a_i. This a_i is paid by advertisers when they want to place advertisement on content i. A coefficient $t > 0$ represents the unattractiveness of the content as an advertising medium, and we assume it is identical in the two forms of content. From equation (2), the more content the end-user uses, the higher the advertiser's utility. By contrast, the end-user and the ISP do not care about how much advertising appears in the content. Thus, in our model, x_i does not depend on a_i.

When CP_i sets the advertising fee to a_i, the advertiser who is indifferent to whether it places its advertisement on content i or not is located at $d = \frac{x_i - a_i}{t}$. Therefore, CP_i's advertising revenue is $\pi_i = a_i \frac{x_i - a_i}{t}$. CP_i optimally sets $a_i = \frac{x_i}{2}$ and receives $\pi_i = \frac{(x_i)^2}{4t}$.

2.3 Internet service provider

The monopolistic ISP provides a single data plan (P, D) to which the end-user must subscribe in order to consume the content, where P represents the subscription fee and D represents the data cap. The end-user pays the subscription fee P to the ISP, and he/she can consume a set amount of content within the data cap D if the ISP does not implement any ZR. I assume that delivering each unit of content generates a cost c. If the content consumed by the end-user is Q, then the ISP's delivery cost is $c \times Q$.

The ISP can propose ZR contracts to either of the CPs or both. The ISP charges a ZR fee S in exchange for ZR. If the CP accepts the proposed contract, it pays S and the end-user can then use as much zero-rated content as they like beyond the data cap. For non-zero-rated content, the end-user can only consume it within the data cap. With regard to the ISP's ZR offer, I assume the following:

Assumption 1 (ZR offer)

1. *If the ISP wants to make ZR contracts with both CPs (open ZR), then it sets a ZR fee S_i^{Op} that will not be turned down by CP_i whether the other CP accepts or rejects the ZR offer. S_i^{Op} can be discriminatory; therefore, the ISP can offer different fees to the two CPs.*

2. *If the ISP wants to make a ZR contract with only one CP (exclusive ZR), then it can make an offer to the objective CP only and exclude the other CP; the ISP can set an exclusive price S_i^E in order to zero-rate CP_i while being concerned solely about whether CP_i will accept or reject the offer.*[9]

Following Somogyi (2017), I use the terminology 'open zero-rating' to express a plan in which all contents are zero-rated. Hereafter let us denote open ZR by Op, exclusive ZR with CP_i by Ei and net neutrality by NN.

Moreover, I assume that the ISP behaves in the following way:

Assumption 2 (ISP's action)

First, the ISP determines the data plan (P, D) to maximize its revenue from the end-user

[9] The ISP can assure CP_i that the ISP will not offer an exclusive ZR contract to CP_j, $j \neq i$, if CP_i rejects the exclusive offer. This assumption is in line with Somogyi (2017). This may not be seen as an advantage for the ISP, and in fact it is different from settings in other studies (e.g. Jehiel and Moldovanu (2000) and Montes et al. (2019)). However, in our model, ensuring net neutrality after the breakdown of negotiation will help the ISP.

without considering the ZR plan, and second, it chooses an optimal ZR plan if necessary.

As I mentioned above, Assumption 2 reflects the situation in which the ISP introduces the ZR service to existing data plans, and this is common case. Moreover, without Assumption 2, the ISP may set an extremely low D (and low P). If D is low, then ZR plans become more attractive for CPs and they will pay a higher ZR fee. That being the case, instead of collecting a small revenue from the end-user, the ISP can collect a large ZR fee from the CPs. Because this study focuses on how the ISP chooses a ZR plan and not on how the ISP determines the data cap, I assume Assumption 2 in order to exclude such a possibility.[10]

2.4 Under net neutrality

First, from Assumption 2, the ISP sets P and D without considering any ZR plans. Because the ISP can raise P up to the end-user's utility u, it chooses D to maximize

$$\tilde{\pi}_{ISP} = u(x_1, x_2) - c \cdot (x_1 + x_2). \tag{3}$$

The ISP sets $D = x_1^* + x_2^*$ where x_1^* and x_2^* represent the end-user's optimal consumption level when a per-unit price is imposed and it is equal to c. Solving this problem, we obtain

$$x_1^{NN} = \frac{2}{3}(2\gamma - 1 - c),\ x_2^{NN} = \frac{2}{3}(2 - \gamma - c) \tag{4}$$

To ensure that consumption becomes non-negative under net neutrality, we assume that $1 < \gamma < 2$ and $0 < c < 2 - \gamma$. Thus the subscription fee and data cap are

$$P = u(x_1^{NN}, x_2^{NN}) = \frac{2}{3}\left(1 - \gamma + \gamma^2 - c^2\right) \tag{5}$$

$$D = x_1^{NN} + x_2^{NN} = \frac{2}{3}(1 + \gamma - 2c). \tag{6}$$

Under net neutrality, CP_i sets $a_i = \frac{x_i^{NN}}{2}$ and obtains advertising revenue

$$\pi_1^{NN} = \frac{(2\gamma - 1 - c)^2}{9t},\ \pi_2^{NN} = \frac{(2 - \gamma - c)^2}{9t}. \tag{7}$$

[10] In Jullien and Sand-Zantman (2018), the network provider distorts the data cap downward relative to an efficient level to raise the attractiveness of the ZR plan in equilibrium. Strategic use of the data cap by ISPs is analyzed in more detail by Economides and Hermalin (2015) and Chillemi et al. (2020).

2.5 Timing

I consider the following timing:

0. Under net neutrality, the ISP offers a data plan (P, D), under which $P = u(x_1^{NN}, x_2^{NN})$ and $D = x_1^{NN} + x_2^{NN}$. The end-user consumes x_1^{NN} of content 1 and x_2^{NN} of content 2.

1. The ISP makes a ZR offer to one or both CPs, setting ZR fee S. It can choose not to make any ZR offers and receive no ZR fees.

2. CPs that receive the ZR offer decide simultaneously whether to accept or reject it.

3. CPs sets advertising fee a_i and the end-user determines consumption levels.

3 Equilibrium analysis

At stage 1, the ISP has four ZR choices; ZR CP_1 exclusively, ZR CP_2 exclusively, implementing open ZR and not implementing any ZR. The ISP selects one of the four to maximize its revenue.

3.1 ZR plans

Before checking the ISP's choice, we examine what happens when each ZR is implemented. If the ISP does not choose any ZR plans, the net neutrality result arises.

3.1.1 Open ZR

If the ISP chooses open ZR, then the end-user increases his/her consumption to the level at which his/her marginal utility is equal to 0. The end-user's consumption levels become

$$x_1^{Op} = \frac{2}{3}(2\gamma - 1),\ x_2^{Op} = \frac{2}{3}(2 - \gamma) \tag{8}$$

and the CPs' profits are

$$\pi_1^{Op} = \frac{(2\gamma - 1)^2}{9t},\ \pi_2^{Op} = \frac{(2 - \gamma)^2}{9t}. \tag{9}$$

3.1.2 Exclusive ZR with CP_1

When the ISP implements $E1$, the end-user increases his/her consumption of content 1 to the level at which marginal utility is equal to 0. By contrast, he/she increases his/her consumption of content 2 as long as the marginal utility gain is larger than 0 within the data cap D. The end-user's optimization problem is

$$\max_{x_1,x_2} \quad u = \gamma x_1 + x_2 - \tfrac{x_1^2+x_1x_2+x_2^2}{2} \tag{10}$$

$$s.t. \quad x_2 \leq D = \tfrac{2}{3}(1+\gamma-2c) \tag{11}$$

We must consider two possibilities; consumption of content 2 is constrained by the data cap D or not. In other words, the end-user may or may not be satisfied with the consumption of content 2 within D.

If the constraint is not binding, the end-user's optimization problem yields consumption levels that are identical to those under open ZR. By contrast, if the constraint is binding, then we obtain

$$x_1^{E1} = \frac{1}{3}(2\gamma - 1 + 2c),\ x_2^{E2} = \frac{2}{3}(1+\gamma-2c) \tag{12}$$

and therefore, the CPs' profits are

$$\pi_1^{E1} = \frac{(2\gamma-1+2c)^2}{36t},\ \pi_2^{E1} = \frac{(1+\gamma-2c)^2}{9t}. \tag{13}$$

The condition under which the constraint is binding is

$$\left(\frac{1}{2} < c \leq \frac{3}{4} \text{ and } 1 < \gamma < \frac{1}{2}(2c+1)\right) \text{ or } \left(\frac{3}{4} < c < 1 \text{ and } 1 < \gamma < 2-c\right). \tag{14}$$

3.1.3 Exclusive ZR with CP_2

When the ISP implements $E2$, the end-user increases his/her consumption of content 2 to the level at which marginal utility is equal to 0. Conversely, he/she increases his/her consumption of content 1 as long as the marginal utility gain is larger than 0 within the data cap D. As well as $E1$, $E2$ leads to two possibilities; the constraint on consumption of content 1 is either binding or not. If the constraint is not binding, $E2$ also yields open ZR consumption levels. If the constraint is binding, the consumption levels are

$$x_1^{E2} = \frac{2}{3}(1+\gamma-2c),\ x_2^{E2} = \frac{1}{3}(2-\gamma+2c) \tag{15}$$

and the CPs' profits are

$$\pi_1^{E2} = \frac{(1+\gamma-2c)^2}{9t}, \; \pi_2^{E2} = \frac{(2-\gamma+2c)^2}{36t}. \tag{16}$$

The condition for the constraint to be binding is

$$\left(0 < c \leq \frac{1}{2} \text{ and } 2-2c < \gamma < 2-c\right) \text{ or } \left(\frac{1}{2} < c < 1 \text{ and } 1 < \gamma < 2-c\right). \tag{17}$$

3.2 ISP's choice

In stage 1, the ISP chooses one of the four options; Open ZR, E1, E2, or NN. Then, the ISP sets and offers ZR fees which are accepted by the designated CPs. We would like to check which options the ISP chooses. From (14) and (17), we have the following three cases and they are illustrated in Figure 1. In each case, we compare the ISP's additional profit from ZR plans, which is the ZR fee minus the increase in the delivery cost. We derive parameter ranges in which the ISP either chooses each ZR plan or chooses no plan.

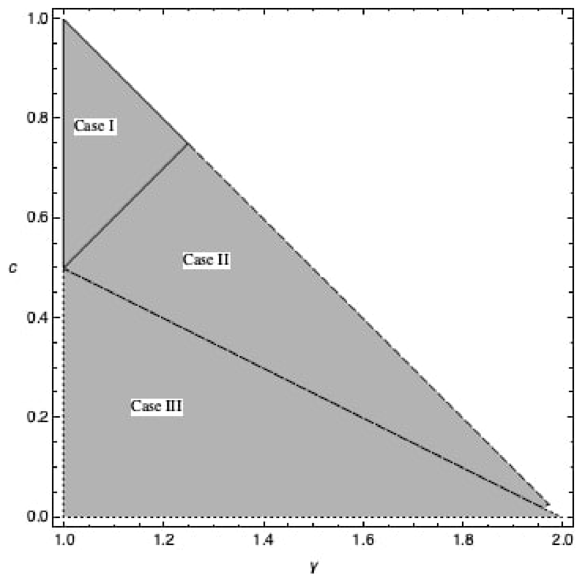

Figure 1: The consequent consumption and therefore ZR fees changes depending on the three cases.

Case I:

Case I emerges when both (14) and (17) hold. In this case, consumption of non-zero-rated content is constrained by the data cap when any exclusive ZR is implemented. Thus, each of the three ZR plans lead to different consumption levels. The condition for Case I is

$CP_1 \backslash CP_2$	Accept	Reject
Accept	$\pi_1^{Op} - S_1^{Op}, \pi_2^{Op} - S_2^{Op}$	$\pi_1^{E1} - S_1^{Op}, \pi_2^{E1}$
Reject	$\pi_1^{E2},\ \pi_2^{E2} - S_2^{Op}$	$\pi_1^{NN},\ \pi_2^{NN}$

Table 1: Payoffs of the CPs' simultaneous Accept-Reject moves when the ISP offers open ZR contracts in Case I.

$CP_1 \backslash CP_2$	Reject
Accept	$\pi_1^{E1} - S_1^{E1},\ \pi_2^{E1}$
Reject	$\pi_1^{NN},\ \pi_2^{NN}$

$CP_1 \backslash CP_2$	Accept	Reject
Reject	$\pi_1^{E2},\ \pi_2^{E2} - S_2^{E2}$	$\pi_1^{NN},\ \pi_2^{NN}$

Table 2: The payoff matrix in Case I when the ISP offers E1 (E2) is the left-hand side (the right-hand side).

(14).[11]

If the ISP wants to implement open ZR, it sets maximal S_i^{Op} for $i = 1, 2$ which is accepted by CP_i despite the actions that CP_j takes. If the ISP wants to implement an exclusive ZR for CP_i, it sets maximal S_i^{Ei}, which is accepted by CP_i given that CP_j rejects it. In Case I, from Table 1 and Table 2, the ISP sets $S_i^{Op} = \pi_i^{Op} - \pi_i^{Ej}$ and $S_i^{Ei} = \pi_i^{Ei} - \pi_i^{NN}$. The ZR revenue changes depending on which plans the ISP chooses.

The total delivery cost also changes depending on the ZR plan. The ISP compares the additional ZR profit, which is the ZR fee minus the additional delivery cost, and chooses the most profitable one.

In Case I, in equilibrium, all three ZR plans and NN can be chosen. In this case, the total consumption is largest under open ZR, then under E1, and then under E2. Therefore, E2 can save the delivery cost; by contrast, it cannot expect a large ZR fee. The converse holds for open ZR. This trade-off brings feasibility to all the ZR plans.

This is the only parameter range in Case I where open ZR is implemented, even though the ISP's delivery cost is relatively large. As we will see below, in Cases II and III, exclusive ZR for their rival contents is not unfavorable for the CPs. In these cases, because the ISP's delivery cost is small and the end-user has been assigned a sufficiently large data cap, exclusive ZR and open ZR lead to the same consumption level. Therefore, the CPs do not want to pay for open ZR and the ISP cannot derive revenue from open ZR and does not implement it.

<u>Case II</u>:

In this case, when $E2$ is implemented, consumption of content 1 is constrained by the data

[11] (14) is a sufficient condition for (17).

cap. However, when $E1$ is implemented, consumption of content 2 falls below the data cap. The condition for Case II is

$$\left(0 < c \leq \frac{1}{2} \text{ and } 2 - 2c < \gamma < 2 - c\right) \text{ or } \left(\frac{1}{2} < c < \frac{3}{4} \text{ and } \frac{1}{2}(2c+1) < \gamma < 2 - c\right) \quad (18)$$

In Case II, open ZR and $E1$ bring the same consumption level, so CP_2 does not want to pay for open ZR. Table 1 and Table 2 are modified slightly and we derive $S_1^{Op} = \pi_1^{Op} - \pi_1^{E2}$, $S_2^{Op} = 0$, $S_1^{E1} = \pi_1^{Op} - \pi_1^{NN}$ and $S_2^{E2} = \pi_2^{E2} - \pi_2^{NN}$.

Again the ISP compares the additional profit from each ZR plan and chooses the most profitable one. In Case II, E1, E2, and NN can be chosen. We would like to mention that E1 in Case II leads to the same content consumption level as that under open ZR.

Case III:

In this case, when any exclusive ZR is implemented, consumption of non-zero-rated content falls below the data cap. The condition for Case III is

$$0 < c < \frac{1}{2} \text{ and } 1 < \gamma < 2 - 2c. \quad (19)$$

In Case III, any ZR leads to the same result as open ZR. Thus, the two CPs do not want to pay for open ZR; $S_i^{Op} = 0$ and $S_i^{Ei} = \pi_i^{Op} - \pi_i^{NN}$. We can check $S_1^{E1} > S_2^{E2}$ in Case III, and therefore only E1 can be implemented. In Case III, E1 or NN is chosen. This E1 leads to the consumption level under open ZR.

We summarize the above results in the following proposition.

Proposition 1

The ISP chooses

- *E1, E2, open ZR or NN in Case I,*
- *E1, E2 or NN in Case II,*
- *E1 or NN in Case III.*

Note that E1 in Cases II and III lead to a similar consumption level as that under open ZR.

In our model, open ZR leads to the largest consumption of the three ZR plans. However, the ISP implements open ZR only when its delivery cost is relatively large. This is because the ISP has set a sufficiently large data cap for the end-user when its delivery cost is small, and it cannot derive revenue from open ZR. It is also notable that in Cases II and III, E1 leads to open ZR consumption. Therefore, we can conclude that if the ISP implements exclusive ZR for the higher quality CP (CP_1), it is not always unfavorable for the lower quality CP (CP_2). To judge whether the competition between CPs is distorted or not, we should consider the size of the data cap.

4 Comparative statics

4.1 When c is small ($0 < c \leq \frac{1}{2}$)

When $0 < c \leq \frac{1}{2}$, the ISP chooses E1 or NN; the ISP does not choose open ZR and E2. Again note that E1 leads to a similar consumption level as that under open ZR when $0 < c \leq \frac{1}{2}$. Therefore, CP_2 does not want to pay for open ZR. This is why open ZR is not implemented even though the ISP can deliver content at a low cost. Furthermore, E2, which is less profitable than E1 and open ZR, is chosen when $c > \frac{1}{2}$ because it is the ZR plan that costs the least. When $0 < c \leq \frac{1}{2}$, the ISP prefers E1 to E2 because it does not have to worry too much about its delivery cost.

The ISP's choice between E1 or NN mainly depends on the value of t. We can derive the following proposition.

Proposition 2

When $0 < c \leq \frac{1}{2}$, then E1 is implemented if t is below $\bar{t}$, and NN is chosen if t exceeds $\bar{t}$, where $\bar{t} \equiv \frac{4\gamma-2-c}{12c}$. Moreover, $E1$ (NN) is more (less) likely to be implemented when γ increases or c decreases.

The ISP faces a trade-off between receiving the ZR fee, $S_1^{E1} = \pi_1^{Op} - \pi_1^{NN}$, and incurring an increase in delivery cost by choosing $E1$. If t is small, then the ISP can set a large ZR fee which exceeds additional delivery cost because CPs can attract more advertisers. By contrast, if t is large, the additional delivery cost exceeds the ZR revenue.

Moreover, the threshold $\bar{t}$ increases as γ increases or as c decreases. If γ increases, the end-user gets higher utility from content 1, therefore the data cap D increases. At the same time if γ increases, x_1^{NN} and x_1^{Op} increase, but x_2^{NN} and x_2^{Op} decrease because the end-user spends more time or data to consume content 1. These effects are combined and cancel each other out, the additional delivery cost, $c(x_1^{Op} + x_2^{Op}) - c(x_1^{NN} + x_2^{NN})$, does not depend on γ. However, $S_1^{E1} = \pi_1^{Op} - \pi_1^{NN} = \frac{(x_1^{Op})^2 - (x_1^{NN})^2}{4t}$ increases with γ. Therefore, $E1$ is more likely to be chosen if γ increases.

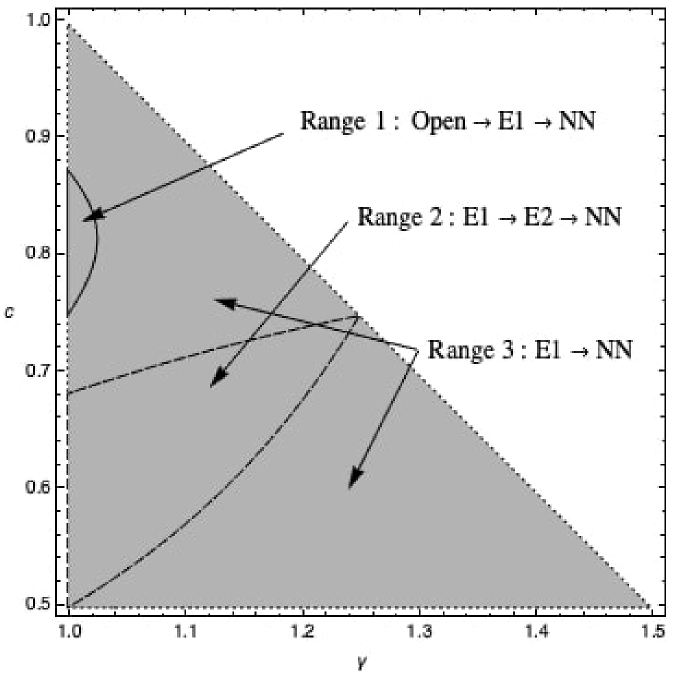

Figure 2: When $\frac{1}{2} < c < 1$, Case I and part of Case II can be rearranged into three ranges.

Next we move on to considering the effect of an increase in c. If c increases, the data cap D decreases, therefore π_1^{NN} decreases. Conversely, because π_1^{Op} does not depend on D and c, $S_1^{E1} = \pi_1^{Op} - \pi_1^{NN}$ increases with c. Needless to say, the additional delivery cost, $c(x_1^{Op} + x_2^{Op}) - c(x_1^{NN} + x_2^{NN})$, also increases with c. When $0 < c \leq \frac{1}{2}$, the latter effect exceeds the former, therefore, $E1$ is less likely to be chosen when c increases.

4.2 When c is large ($\frac{1}{2} < c < 1$)

When $\frac{1}{2} < c < 1$, to see the effect of changes in t on the ISP's choice needs three further case studies. The three cases are shown in Figure (2). We conduct comparative analysis in each range.

First, consider parameter Range 1. In this range, the ISP's choice changes as *open* $\rightarrow$ $E1 \rightarrow NN$ as t increases from 0. The second case is Range 2, where the ISP's choice changes as $E1 \rightarrow E2 \rightarrow NN$ as t increases from 0. The third case is Range 3, where the ISP's choice changes as $E1 \rightarrow NN$ as t increases from 0.

In each range, we perform comparative statics in a similar manner to the small c case; we will see the effect of a change in γ or c on the threshold of t at which the ISP's choice changes. The results are summarized in Table (3).

We would like to focus on the effect of c in Range 1 and the effect of γ in Range 2.

	$\uparrow \gamma$	$\uparrow c$
Range 1		
Open	Negative	Inverse U-shape
E1	Positive	Positive or Negative
NN	Negative	Positive
Range 2		
E1	U-shape	U-shape
E2	Inverse U-shape	Inverse U-shape
NN	Positive or Negative	Positive or Negative
Range 3		
E1	Positive or Negative	Positive or Negative
NN	Positive or Negative	Positive or Negative

Table 3: Effect of γ and c on breadth of t where the ISP chooses each ZR or NN when $\frac{1}{2} < c < 1$. Note that γ and c have a similar effect on NN in Range 2; conversely, they have the opposite effect on E1 and E2 in Range 2, and on E1 and NN in Range 3.

An increase in c not only has a negative effect but also a positive effect on profit from ZR plans. First, of course, as c increases, additional delivery costs from the ZR plans increase. Second, a larger c means larger marginal costs for the ISP and it sets a lower data cap. Therefore, the ZR plans become more attractive to the CPs, that is, ZR fees increase. In Range 1, because the consumption under open ZR is higher than that under E1, the delivery cost under open ZR is increased more by an increase in c. When the second effect on open ZR is sufficiently large compared with the first effect, open ZR is more likely to be chosen as c increases. Consequently, the breadth of t where open ZR is chosen is maximized when c is mid-level; when $c = \frac{8\gamma^2-20\gamma+5}{4(2\gamma-5)} + \frac{1}{4}\sqrt{\frac{32\gamma^3-120\gamma^2+120\gamma-25}{(2\gamma-5)^2}}$. This line emerges in the figure on the right in Figure 3; the line in Range 1.

Next, we consider the effect of γ in Range 2. An increase in γ affects both the additional profit from E1 and E2. First, if γ is high, content 1 is consumed more and the ISP can set a higher ZR fee for E1, even though it leads to the same consumption as under open ZR in Range 2. By contrast, the additional delivery cost does not depend on γ. From the above two effects, the additional profit from E1 increases in γ. Second, an increase in γ has a different effect on E2; both the ZR fee and the additional delivery cost decrease in γ. Therefore, γ may make not only E1 but also E2 more profitable. We can conclude that there are parameter ranges where E2 becomes more likely to be chosen as γ increases. The breadth of t where E2 (E1) is chosen is maximized (minimized) when $c = \frac{2\gamma-1}{2}$. This is the line in Range 2 in Figure 3.

The results for the other ranges are shown in Figure (3) and Figure (4). As we have seen so far, γ and c can increase and decrease the possibility of each ZR. In particular, an increase in γ does not always mean that E1 is likely to be implemented. An increase in γ increases the ISP's delivery cost too much or makes open ZR more attractive. Furthermore, γ and c have opposite effects on the ISP's choice, however, they have the same effect in specific ranges.

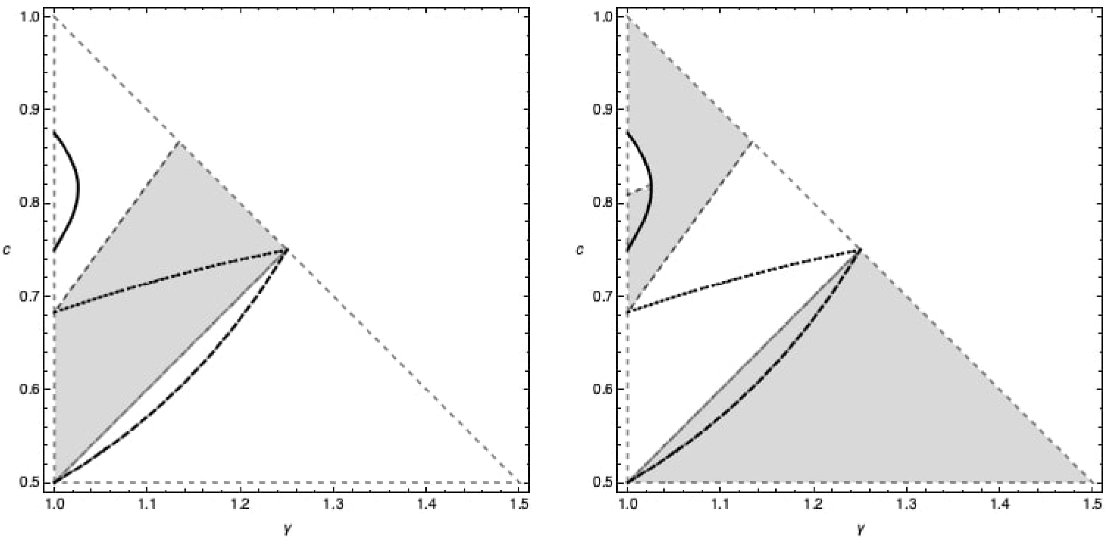

Figure 3: Effect of γ (c) on E1 is shown in the figure on the right (left). The white areas represent the positive effect and the gray areas represent the negative effect.

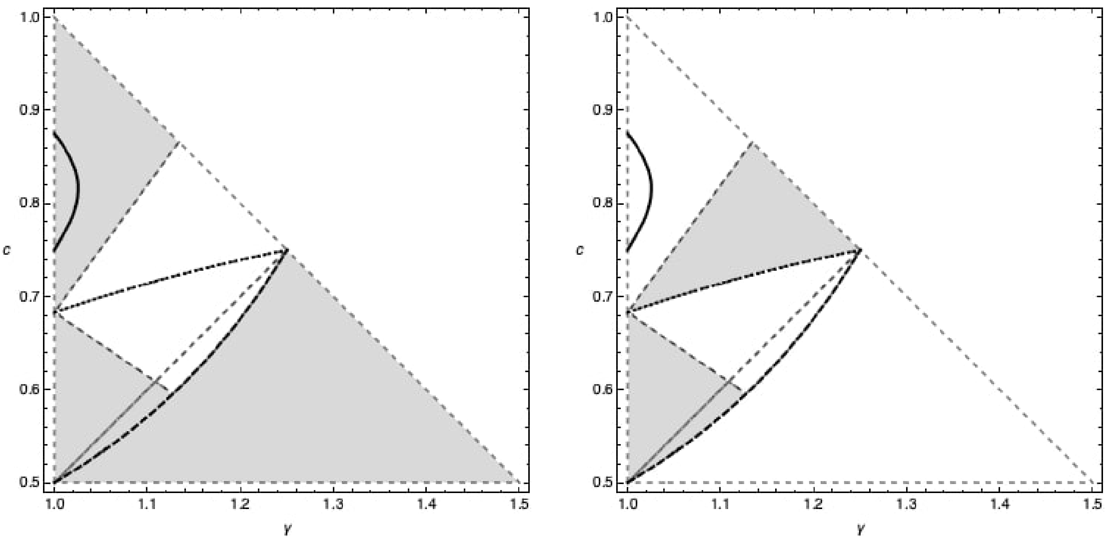

Figure 4: Effect of γ (c) on NN is shown in the figure on the right(left).

ISP's choice	Resulting consumption level	Welfare maximizing consumption level
E1	E1	E1 or Open
	Open	Open
E2	E2	E1 or Open
Open	Open	Open
NN	NN	E1, E2, Open or NN

Table 4: The ISP's choices and the socially optimal consumption levels. In the consumption level column, E1 and E2 represent the consumption level when the non-zero-rated content is constrained by the data cap.

5 Welfare analysis

In our welfare analysis, we define social welfare as the sum of the ISP's profit, the two CPs' profits, and consumer surplus. The ISP's profit is subscription fee, P^*, minus delivery cost, $c(x_1+x_2)$, plus ZR fees. The sum of the two CPs' profits is their advertising revenue minus ZR fees. Consumer surplus is the end-user's utility, $u(x_1, x_2)$, minus the subscription fee, P^*. First, we can define the following lemma about consumer surplus.

Lemma 1

Consumer surplus is maximized under open ZR. In addition, the sum of the CPs' advertising revenues is also maximized under open ZR.

Because the subscription fee is fixed, consumer surplus depends on the end user's utility. Open ZR allows the end-user to consume as much content as he/she desires. Moreover, the consumption is maximized under open ZR. This is why Lemma 1 holds. Next, we show the welfare-maximizing ZR plans in Table 4.

We would like to discuss the result from Table 4. First, when open ZR is chosen or consequently open ZR consumption level is realized, the ISP's choice is optimal for social welfare. From Lemma 1, consumer surplus and the CPs' advertising revenue are maximized under open ZR; if the ISP's total delivery cost is not so large, open ZR may be welfare optimal. In equilibrium, open ZR is actually welfare optimal when it is realized. Moreover, the ISP's choice leads to consumption less than or equal to the socially optimal level. This is because the ISP does not take the end-user's surplus and a part of the CPs' advertising revenue into account, but social welfare includes them. We summarize these results in the following proposition.

Proposition 3

When open ZR is chosen or consequently open ZR consumption level is realized, the ISP's choice is optimal for social welfare. When the other consumption level is realized, it is less than or equal to the socially optimal level.

6 Effect of vertical integration

Finally, in this section we consider the situation where the ISP and one of the two CPs are integrated. As before, the ISP has four choices; E1, E2, open and NN. Furthermore, ZR fees are determined in the same way as before. The ISP chooses on option which maximizes the sum of (1) the affiliated CP's profit and (2) the ZR revenue, which is the ZR fee from the unaffiliated CP minus the ISP's additional delivery cost.

6.1 When the ISP is integrated with CP_1

First, we consider the situation where the ISP is integrated with CP_1. In this case we yield the following proposition.

Proposition 4

If the ISP is integrated with CP_1, the ISP chooses

- *Open, E1, E2 or NN in Case I.*
- *E2 or NN in Case II.*
- *E2 or NN in Case III.*

In Case I, the three ZR plans lead to different results from each other. Even though the ISP takes CP_1's profit into consideration, the all plans can be chosen in Case I. However, because the delivery cost decrease and the data cap increases, CP_1 can generate relatively large profit even though it is not exclusively zero-rated in Case II. For this reason, the ISP stops treating CP_1 favorably and attempts to collect a ZR fee from CP_2. Additionally, in Case III, E1, E2 and open lead to the same consumption level, thus the ISP implements E2 to collect a ZR fee from CP_2.

6.2 When the ISP is integrated with CP_2

Similarly we consider the situation when the ISP is integrated with CP_2.

Proposition 5

If the ISP is integrated with CP_2, the ISP chooses

- *Open, E1 or NN in Case I.*
- *E1 or NN in Case II.*
- *E1 or NN in Case III.*

The difference is that the ISP does not choose exclusive ZR for its affiliated CP when the ISP is integrated with CP_2. In Case I, because the ISP is integrated with the less popular CP, the ISP prefers collecting ZR fees from CP_1 to increasing CP_2's profit. In Case II and Case III, the ISP implements exclusive ZR for the unaffiliated CP in order to collect a ZR fee from the CP as before.

From the results above, when the delivery cost is low, the ISP zero-rates the unaffiliated CP to gain revenue from the ZR fee. On the other hand, when the delivery cost is high, the ISP implements exclusive ZR for the unaffiliated CP or Open ZR. The integrated ISP balances the affiliated CP's profit and zero-rating fee from the unaffiliated CP. This trade-off is similar to that observed in the literature, which focuses on vertically integrated producers and dual distribution channel.[12]

7 Concluding remarks

This study considers the effect of the ISP's marginal cost, the difference between the CPs' quality and advertising power on the ISP's ZR decision. In our model, all three ZR plans can be chosen in equilibrium. The three plans differ in the resulting consumption and therefore the ISP faces a trade-off between high ZR fees and large total delivery cost.

We show that the ISP's choice changes depending on (1) the ISP's marginal cost to deliver content, (2) the difference between the quality of the content provided by the two CPs and (3) the two CPs' advertising power. In particular, the ISP's marginal cost plays an important role in determining the resulting consumption levels under each ZR plan. Depending on the data cap that is preset by the ISP, an exclusive ZR may lead to the same consumption as an open ZR. In this case, exclusive ZR is not unfavorable for non-zero-rated CPs.

[12]The monopolistic supplier that has its own retail channel and the rival retailer that buys the intermediate goods from the supplier attempt to balance their retail profit and wholesale profit. See, e.g., Sappington and Unel (2005); Arya and Mittendorf (2018) for details.

From comparative statics, we can conclude that if the CP's advertising power, t, increases, the ZR plan that results in a lower total amount is likely to be chosen, and finally net-neutrality is chosen. The effects of the ISP's delivery cost and of the difference between the quality of the CPs' content are slightly complicated. They may affect both the total delivery cost and the ZR fees, therefore, they can make ZR plans both more profitable and less profitable. We demonstrate that an increase in the ISP's marginal cost makes it more likely that a ZR plan resulting in heavy traffic will be implemented, and an increase in the difference between the content quality makes it less likely that a ZR plan in favor of the higher quality CP will be implemented.

For social welfare, in equilibrium, the ISP's choice results in the amount of consumption which is less than or equal to the optimal level. This is because the ISP does not take the end-user's surplus and a part of the CPs' advertising revenue into account. Enabling the ISP to collect ZR fee from CPs is not sufficient to achieve socially optimal consumption level. The end-users may have to absorb an increase in the ISP's delivery cost to enjoy more online contents.

When the ISP is integrated with one CP, the ISP zero-rates the unaffiliated CP to gain revenue from the ZR fee when the delivery cost is low. On the other hand, when the delivery cost is high, the integrated ISP balances the affiliated CP's profit and zero-rating fee from the unaffiliated CP. Consequently, it implements exclusive ZR for the unaffiliated CP or Open ZR.

Throughout this paper, the size of the data cap is a important factor. It determines the resulting consumption levels. Depending on the data cap, not-zero-rated CP may benefit from ZR. Therefore, in order to judge whether the competition between CPs is distorted or not, we need to consider the size of the data cap.

It should be noted that these results depend on Assumption 2, which inhibits the ISP from resetting the data cap and the subscription fee. Under this assumption, we analyze the situation in which the ISP introduces ZR plans into a market where the data cap and the subscription fee have taken root. Removing this assumption is left for future research.

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