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Net Neutrality: An Economic Analysis

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
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Abstract

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This paper explores the filed of net neutrality. Specifically, it analyzes the social welfare implications of the zero-price rule and discrimination effects. On one hand, when the consumers can only choose either good 1 or good 2, there exists a market with competitive prices for both goods when the Internet service providers (ISP) discriminates by charging a fee to only one of the content providers (CPs). Under net neutrality, only one content provider can sustain positve prices, resulting in losses in consumer's utility, profits of firms, and ultimately the decrease in social welfare. On the other hand, when consumers can choose to buy good 1, good 2, or both goods, net neutrality proves to be more welfare enhancing because of an increase in the number of Internet users, total profits of the CPs, and the total consumer's utility.

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1. Introduction

The topic of net neutrality is one of the most debated and controversial issues since the age of the Internet. Net neutrality is a principle that Internet users have no restrictions on their online experience. The concept requires for the equal treatment of all information packets across the network. It calls for the Internet service provider (ISPs) to be completely neutral regarding what is sent over networks and that no bit of information should be prioritized over another. In theory, these network providers cannot distinguish where these packets are sent because all packets should be equal. This idea leads to the debate of non-discrimination of network users and the banning of engagement in traffic control and prioritizing usages.

However, as the number of Internet users is expanding, coupled with introductions of new technologies such as smart phones and other Internet enabled devices, there is a huge surge in demand for high-bandwidth content. The resulting congestion has led to a demand for traffic management increases. Currently, ISPs can track and monitor traffic. Content providers (CPs) for websites would pay their monthly fees to an ISP and any bit of information among the content providers would make the same trek. However, network providers have the ability to discriminate their users and their connection quality. A consequence of this action is the difference in speed quality in the user experience, creating an inequality among content providers based on special interests of the ISPs. A network operator that has a vertically integrated business model that includes a content provision sector has incentive to degrade its competitor's access. For example, an ISP can create its own search engine and limit bandwidth to google.com or yahoo.com so that its users would more likely switch to the new search engine.

On the other hand, net-neutrality also affects Internet users. In theory, two users paying the same price for Internet should experience the same connection quality. Yet, ISPs impose a tiered service model for its users in order to control bandwidth, creating an artificial scarcity to remove competition for its uncompetitive services. Since each area has a limited amount of bandwidth through its Internet cables servicing its vicinity, when a user requires a large amount of bandwidth for its daily activity that clogs up Internet for the rest of the users in the area, the internet service provider might limit the user's bandwidth in order to free up some bandwidth for other users.

In short, the Internet space can be separated to three groups as shown in Figure 1. ISPs have a huge influence and exercise considerable market power in cyberspace, since they enable content providers to access Internet users. It is unclear whether their ability to manipulate bandwidth distributions and discriminate among their users is subject to regulatory oversight by the Federal Communications Commission.[1] In addition, competition among ISPs is not fierce, especially in less populated areas, as most households receive Internet through their cable or telephone companies. Without net-neutrality, these ISPs can change the speed and quality of Internet usage for their customers without their consent.

The ISPs' main argument is that net-neutrality is a technical principle and not a legal one. They insist that net-neutrality is not in danger. They also warn that increased government regulation will lead to some unintended consequences, as the government will pay more attention to Internet traffic. For example, millions of jobs will be lost if as companies view the industry as less lucrative and invest less due to more government regulations. Many ISPs have accused Google and Skype of freeloading for using a network of lines and cables the phone companies

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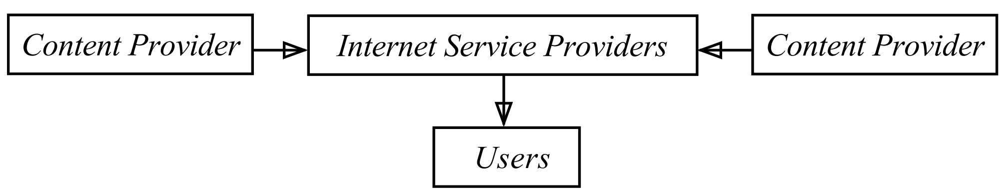
[1] Currently, there is a lawsuit in the courts between Comcast and the FCC about regulation rights the FCC has over the firm. See Banerjee and Mialon (2011).

spent billions of dollars to build. However, the ISPs provides a form of price discrimination that would reduce the return on investment for Internet content—meaning website owners, bloggers, newspapers, and businesses would have less incentive to expand their sites and applications.

Some argue that the role of government should not be to micro-manage ISPs such as Comcast, but should instead provider consumers with alternatives in an industry that lacks competition. There is an argument that since websites such as YouTube stream as much data in three months as the world's radio, cable and broadcast television channels stream in one year, these companies should pay a premium for their usage because networks are not prepared to handle such high usage. The ISPs argue that there is a limit on available bandwidth and endanger innovation. Without network neutrality, there is an effective fund transfer from the competitive layers of content providers to the monopolistic nature of the ISPs.

Figure 1: The Structure of the Internet[2]



In his literature survey, Shuett (2010) reviews the small but growing research area of network neutrality. He categorizes the field into two main areas. The first area deals with the non-discrimination issue of net-neutrality. This includes menu pricing for its customers and charging the CPs a premium for its bandwidth usage, as well as a vertically integrated ISP degrading its rivals' traffic. In Hermalin and Katz's (2007) model, they showed that with a monopolistic ISP, which only offers a single connection quality with a market of three quality preferences, has an overall effect on welfare that is often negative without menu pricing. They

[2] The ISP serves as a connector between the CPs and the users by providing a network infrastructure (Internet) for interactions.

also found that charging all consumers at the price of the highest quality constricts the market demand, but not charging the CP results in a less than efficient connection quality. Meanwhile, Choi and Kim (2010) argue that the prioritization of traffic returns a higher short-term welfare if and only if the profit margins of the two firms are large enough with respect to their sensitivity to waiting costs of slower bandwidth. With the assumption that waiting costs are not determined mechanically, they also show that the ISP increases its profits with degradation of connection quality even if it is not vertically integrated.

The second area of the literature focuses on the zero-price rule in net-neutrality. The Internet is considered a two-sided market because of the existence of network externalities. Both the content provider and consumers requires the ISP to provide Internet services for access. The number of CP and consumers are mutually beneficial to each other, but both are restricted to the fees the ISP imposes. Economides and Tåg (2009) includes Armstong's (2006) membership fee model to show that charging the CPs a fee may decrease social welfare, with the assumption that CPs value more customers than the consumers value more CPs. However, it also illustrates that the consumers benefit from a CP fee because their Internet fees will be lowered as a result to attract a larger Internet user base. In the model of multiple ISPs in each local market, Musacchio, Schwartz, and Walrand (2009), discuss the benefits of the zero-price rule because it encourages market entry to the CP market. Lee and Wu (2009) add that fees might lead to fragmentation, like cable television, where some content are only available to users from one ISP. However, the social welfare under non-neutrality is lower compared to that under the zero-price rule. Recently, Banerjee and Mialon (2011) in an unpublished mimeo show that the ISPs' last mile access charges to content network platforms (CNP) increases consumer welfare by lowering the price of Internet connection for consumers. They also explore the effects of vertical integration of an ISP and a CNP and found that integration decreases competition between CNPs. In the case where each CNP integrates with the local ISP, the advertising fees are less than the level under NN with out integration, but the consumers will experience a higher Internet fees.

My paper bridges the two areas by combining the concept of zero-price rule and non-discrimination of network neutrality. In the first model, there exists a monopolistic ISP with two CPs. In this market, CP_1 offers content of good 1 and CP_2 offers content of good 2. The consumer can buy access to good 1, buy access to good 2, or not buy either. I then explore the model under the zero-price rule, where CPs are not charged a fee, versus the discrimination rule, where the ISP discriminates and only charge CP_1 a fee. Under the assumption that all consumer values good 1 over good 2, we see that under the zero-price rule, an equilibrium where both CPs produce at positives prices is impossible given the set of parameters. From this result of a single good market under network neutrality, I show that the market with discrimination from the ISP results in the sustainability of both CPs and a higher social welfare. In my second model, I expand the first model by allowing for the consumer to purchase either goods or both goods. I apply the zero-price rule under network neutrality and the discrimination rule under non-network neutrality. Here, both scenarios lead to equilibrium of positive prices.

The organization of my paper is as follows. Section 2 explores my first model with comparative statics analysis and welfare comparison. In Section 3, we study how expanding consumer preferences affect social welfare under the same assumptions as in first model. Concluding remarks are given in Section 4.

2. Model 1

In the network neutrality model, suppose that the population, *N*, is normalized to 1. Consider a market with only two content providers, CP_1 and CP_2, each providing one good. The utility of the consumers is characterized by a preference parameter $\theta \in [0,1]$, where each consumer's utility is given by

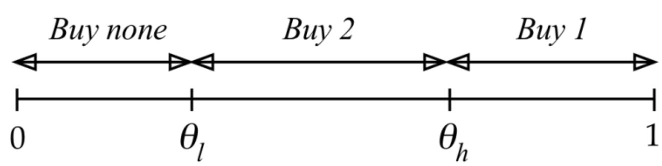
$u_1 = \alpha\theta - p_1 - r$ if he or she buys good 1,

$u_2 = \theta - p_2 - r$ if he or she buys good 2,

$u_0 = 0$ if he or she does not buy.

The parameter $\alpha > 1$ represents how much the consumer values more of good 1 over good 2. The variable r is the Internet subscription fees the consumer pays to the ISP.

Figure 2: A Continuum of Consumer's Value of Good 1 or Good 2



The marginal consumer at θ_h who is indifferent between buying good 1 and good 2 must have the utility u_2=u_1. Solving for *the marginal consumer y*ields

$$\theta_h = \frac{p_1 - p_2}{\alpha - 1}.$$

Anyone who has utilty θ_h or higher will buy good 1. So, the demand for good 1 is

$$q_1 = \frac{\alpha - 1 - p_1 + p_2}{\alpha - 1}.$$

Similarly, the marginal consumer at θ_l who is indifferent between buying good 2 and not buying must have the utility u_l= 0. Solving for θ yields:

$$\theta_l = p_2 + r.$$

Anyone who has utility θ_l or higher will buy good 1. So, the demand for good 2 is

$$q_2 = \frac{p_1 - \alpha p_2 - (\alpha - 1)r}{\alpha - 1}.$$

2.1 Network Neutrality (NN)

Under the zero-price rule, each content provider faces no Internet fees from the ISP. Therefore, the profit functions[3] are $\pi_1 = p_1 q_1$ and $\pi_2 = p_2 q_2$, or

$$\pi_1 = p_1\left(\frac{\alpha - 1 - p_1 + p_2}{\alpha - 1}\right),$$

$$\pi_2 = p_2\left(\frac{p_1 + \alpha p_2 - (\alpha - 1)r}{\alpha - 1}\right).$$

Maximizing the profit functions with respect to prices, CP_1's best-response is

$$p_1 = \frac{(\alpha - 1) + p_2}{2},$$

and CP2's best response is

$$p_2 = \frac{p_1 - (\alpha - 1)r}{2\alpha}.$$

Solving the best responses for the Nash equilibrium, the optimal prices are given by

$$p_1^* = \frac{(\alpha - 1)(2\alpha - r)}{4\alpha - 1},$$

$$p_2^* = \frac{(\alpha - 1)(1 - 2r)}{4\alpha - 1}.$$

Notice that for p_2 to be positive, we need $r < ½$.

For simplicity, we assume that the ISP faces no costs. Therefore, the profit function[4] is

$$\pi_i = r(1 - \theta_l) = r(1 - p_2 - r),$$

[3] For the profit functions of the CPs, the first order conditions holds and the second order condition is negative, ensuring a maximum.
[4] For the profit function of the ISP, the first order conditions holds and the second order condition is negative, ensuring a maximum.

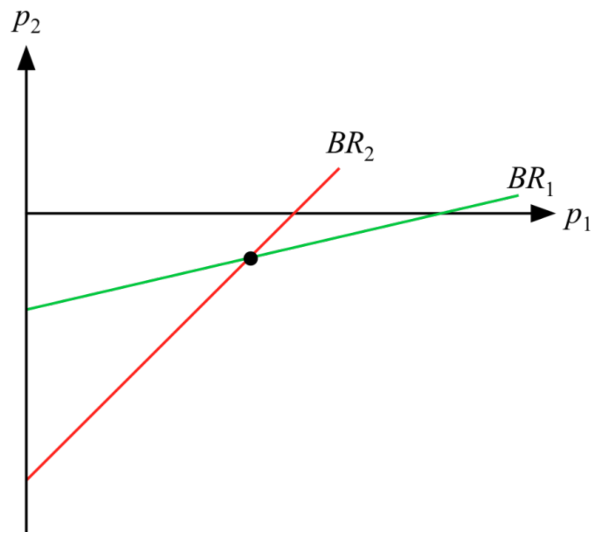
since 1- θ_l consumers will subscribe to the Internet.

Replacing p_2 with p_2* and maximizing ISP's profits with respect to r yields

$$r^* = \frac{3\alpha}{2-4\alpha}.$$

Notice that r* is positive only when $\alpha < ½$. This is a contradiction to our assumption that $\alpha > 1$. Thus, there exists no r* which guarantees both goods are sold at positive prices. When $\alpha = 1.5$, Figure 3 illustrates this case when the CPs best responses do not intersect in the positive quadrant, showing that a Nash equilibrium with positive prices cannot exist.

Figure 3: Best Responses for CP_1 (BR_1) and CP_2 (BR_2) [5]



As a result, the market now only has good 1 produced by CP_1. The new consumer utility is

$$u_1 = \alpha\theta - p_1 - r \quad \text{if he or she buys good 1,}$$

$$u_0 = 0 \quad \text{if he or she buys nothing.}$$

[5] For the graph, r is replaced by r* and $\alpha = 1.5$ in the best response functions.

Suppose θ_n is the consumer who is indifferent between buying good 1 and not buying. Solving for θ_n yields

$$\theta_n = \frac{p_1 - r}{\alpha}.$$

Hence, the quantity demanded is 1- θ_n. CP_1 then faces a profit function of

$$\pi_1 = p_1\left(\frac{\alpha - p_1 - r}{\alpha}\right).$$

Maximizing the profits of CP1 with respect to p_1, we get the optimal price and quantity as

$$p_1^* = \frac{\alpha - r}{2},\ q_1^* = \frac{\alpha - r}{2\alpha}.$$

Next, the ISP only collects Internet fees from one single market, so the profit function is

$$\pi_i = rq_1^* = \frac{r(\alpha - r)}{2\alpha}.$$

Maximizing ISP's profits with respect to r, the optimal rate the ISP should charge its user is

$$r^* = \frac{\alpha}{2}.$$

Replacing r with r^* in q_1^* and p_1^*, we get

$$q_1^* = \frac{1}{4},\ p_1^* = \frac{\alpha}{4}.$$

Similarly, replacing r with r^* in the profit functions CP_1 and ISP, we arrive at an equilibrium where both players are maximizing their profit, given parameter α, and

$$\pi_1^* = \frac{\alpha}{16},\ \pi_i^* = \frac{\alpha}{8}.$$

2.1.1 Comparative Statics

Table 1: Comparative Statics with respect to α[6]

p_1^*	q_1^*	r^*	π_1^*	π_i^*
+	0	+	+	+

Proposition 1. *The profits of CP1 increase as the customer's value of good 1 over good 2 increases.*

Notice that as α increases, the price of good 1 increases and the quantity demanded remains unchanged. Since the profits function of CP_1 is price multiplied by the quantity demanded, the profits would similarly have an identical change. As people value good 1 more, the price of good 1 must adjust to reflect the increase in value. Recall that $q^*=(1-\theta_n^*)$, where $\theta_n^* = \frac{p_1^* - r^*}{\alpha}$. A change in α has no effects on the equilibrium demand suggests that the effect of change in equilibrium price and the equilibrium Internet subscription fee offsets the change in the value consumer has in good 1.

Proposition 2. *The profits of ISP increase as the customer's value of good 1 increases.*

Since the profit function of the ISP at equilibrium is $\pi_i^* = r^* q_1^*$, an increase in Internet subscription fees, r^*, would increase its profits as well while the demand of good 1 remains constant. As consumers value good 1 more, they are willing to pay a higher fee in order to access the content provided by CP_1.

2.2 Non-Network Neutrality (NNN)

In the NN case, we introduce discrimination from the ISP. Here, we assume that the ISP charges CP_1 a fee, while not charging CP_2. CP_1 now faces a new profit function $\pi_1 = (p_1 - s)q_1$,

[6] See Appendix A for the derivations results.

where s is the access charge.[7] CP_2 faces the same profit function as in the previous model, $\pi_2 = p_2 q_2$. The profit functions can be rewritten as

$$\pi_1 = (p_1 - s)\left(\frac{\alpha - 1 - p_1 + p_2}{\alpha - 1}\right),$$

$$\pi_2 = p_2\left(\frac{p_1 + \alpha p_2 - (\alpha - 1)r}{\alpha - 1}\right).$$

Maximizing the profits functions, CP_1's best response is

$$p_1 = \frac{(\alpha + s - 1) + p_2}{2}$$

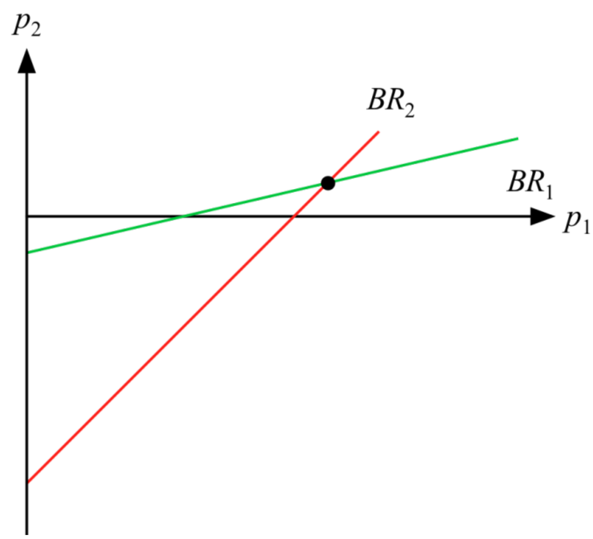
and CP_2's best response is

$$p_2 = \frac{p_1 - (\alpha - 1)r}{2\alpha}.$$

The best responses are shown in Figure 2.2.1. This time, both CPs can produce at positive prices, which allows a market of two goods. The graph shows that the two best responses are strategic complements. As CP_1 increases its prices, CP_2 responds by increases its own prices. Notice that the slope of the best response for CP_2 is steeper than the slope of CP_1's best response, illustrating the price of good 2 is more sensitive to prices changes of good 1 than the alternative case.

[7] For the profit functions of the CP_1, the first order conditions holds and the second order condition is negative, ensuring a maximum.

Figure 4: Best Responses for CP_1 (BR_1) and CP_2 (BR_2) [8]



Solving simultaneously for the Nash equilibrium, the optimal prices are given by

$$p_1^* = \frac{(\alpha-1)(2\alpha-r)+2\alpha s}{4\alpha-1},$$

$$p_2^* = \frac{(\alpha-1)+(1-2r)+s}{4\alpha-1}.$$

Next, the ISP now receives the Internet fees, *s,* from CP_1 in addition to the Internet fees, *r*, from Internet users. The ISP profit function[9] is then

$$\pi_i = r(1-\theta_l)+s(1-\theta_h) = r(1-p_2-r)+s\left[1-\left(\frac{p_1-p_2}{\alpha-1}\right)\right].$$

Solving the first order conditions simultaneously, we obtain r^* and s^*, such that

$$r^* = \frac{1}{2},$$

$$s^* = \frac{\alpha-1}{2}.$$

[8] For the graph, r is replaced by r^* and $\alpha = 1.5$ in the best response functions.
[9] For the profit functions of the ISP, the first order conditions holds and the Hessian matrix is negative definite and the determinant is positive, ensuring a maximum.

At equilibrium where all players are maximizing their profits given a parameter α, after we replace *r* with *r** and *s* with *s**, the CPs have demands of

$$q_1^* = \frac{\alpha}{4\alpha - 1},$$

$$q_2^* = \frac{\alpha}{8\alpha - 2},$$

and prices of

$$p_1^* = \frac{6\alpha^2 - 7\alpha + 1}{8\alpha - 2},$$

$$p_2^* = \frac{\alpha - 1}{8\alpha - 2}.$$

Thus, the profits of the CPs become

$$\pi_1^* = \frac{\alpha^2(\alpha - 1)}{(4\alpha - 1)^2},$$

$$\pi_2^* = \frac{\alpha(2\alpha - 1)}{4(4\alpha - 1)^2}.$$

Meanwhile, the ISP profit function becomes

$$\pi_i^* = \frac{\alpha(2\alpha + 1)}{4(4\alpha - 1)}.$$

2.2.1 Comparative Statics

Table 2: Comparative Statics with respect to α [10]

p_1^*	p_2^*	q_1^*	q_2^*	Q^*	s^*	r^*	π_1^*	π_2^*	π_i^*
+	+	-	-	-	+	0	+	+	+

[10] See Appendix A for derivation results.

Proposition 3. *The profits of CP_1 and the profits of CP_2 both increase as the customer's value of good 1 over good 2 increases.*

As α increases, the price of good 1 increases but CP_1 also faces higher Internet fees from the ISP. Meanwhile, the price of good 2 also increases as a result of an increase of α. Since both CPs face a downward sloping demand curve, higher prices shrink the demand for both goods. However, we know that the price effect is larger than the quantity effect because both CPs' profits increase.

Proposition 4. *The profits of the ISP increase as the customer's value of good 1 over good 2 increases.*

The ISP collects Internet fees from consumers and CP_1. The change in α does not affect the r^*. This suggests that the ISP collects less fees from consumers, since the total demand of both markets, Q^*, decreases. On the other hand, it collects s^* from CP1. Overall, we know that the increase in profits has a larger effect than the decrease in r^* to the ISP's profits because its total profits increases as a result of an increase of profits.

2.3 Welfare Comparisons

At the equilibrium, we calculate the total utility of all consumers in each market by integrating along the continuum of θ within the market demand. In the case of NN, the market size is 1-θ_n. Integrating the utility function from θ_n to 1, the total utility to buyers of good 1 is

$$U_1^{NN} = \frac{1}{32\alpha}.$$

Under NN, the total utility in CP1's market,[11] 1-θ_h, is

$$U_1^{3N} = \frac{\alpha^2(\alpha+1)}{2(4\alpha-1)^2},$$

[11] See Appendix A for the functions of integral.

and total utility in CP2's market,[12] θ_h - θ_l, is

$$U_2^{3N} = \frac{\alpha^2}{8(4\alpha-1)^2}.$$

We prove that $U_1^{NN} < U_1^{3N} + U_2^{3N}$ by substitution, and since $\alpha > 1$, we get

$$1 < 4\alpha(4\alpha^4 + 5\alpha^3 - 4\alpha^2 + 2).$$

This inequality shows that the total utility under NN is greater than that under NN. In order words, consumers receive more satisfaction under a market of two goods with two CPs compared to a market of only one CP producing only one good. One reason for this difference is the level quantity demanded in each model. In the NN model, total demand is $Q^{NN} = q_1^{NN}$. In the NNN model, total demand is $Q^{3N} = q_1^{3N} + q_2^{3N}$. Comparing $Q^{NN} < Q^{3N}$, we substitute in the demand functions at the equilibrium

$$\frac{1}{4} < \frac{3\alpha}{8\alpha-2}, \text{ or}$$

$$-1 < \alpha.$$

As a result of expanded demand under the NNN model, more of the population is participating in the market and consuming good 1 or good 2.

The driving force of the increased total demand directly affects the total profits of the CP's as well. $\prod_{cp}^{NN} = \pi_1^{NN}$ represents the total CP profits in the NN model, and $\prod_{cp}^{3N} = \pi_1^{3N} + \pi_2^{3N}$ represents the total CP's profits in the NNN model. Again we show that $\prod_{cp}^{NN} < \prod_{cp}^{3N}$ through substitution of the profits at equilibrium, we prove that

$$\frac{\alpha}{16} < \frac{4\alpha^3 + 3\alpha^2 - \alpha}{4(4\alpha-1)^2}, \text{ or}$$

$$1 < 4\alpha.$$

---

[12] See Appendix A for the functions of integral.

The total CP profits is greater in the NNN than that of the NN model because the greater demand of goods leads to more quantity sold for the CP's, which drives up the profits of each of the CP's. Recall that CP_2 could not even produce at a positive price in the NN model, as CP_1's advantage over CP_2 of α pushes CP_2 out of the market at the Nash equilibrium of their best responses because CP_2 would have a negative profit if it produces. On the other hand, with the introduction of s, CP_1's Internet fees to the ISP, added to CP_1's profit function, it now has to pay a fee per unit sold. CP_2 could now produce good 2 at positive prices.

Meanwhile, in equilibrium, the ISP's profit is $\prod_i^{NN} = \pi_i^{NN}$ in the NN and $\prod_i^{3N} = \pi_i^{3N}$ in the NNN model. We prove that $\prod_i^{NN} < \prod_i^{3N}$ by substituting the profits, and we get

$$\frac{\alpha}{8} = \frac{\alpha(2\alpha+1)}{4(4\alpha-1)}, \text{ or}$$

$$-1 < 2 .$$

The ISP's profits clearly increases in the NNN model because it receives revenues from the number of subscriptions to the Internet because more consumers are entering the market for goods as shown by the increase in total demand. In addition, the ISP also gains a new stream of revenue from charging CP_1 a fee based on the demand of good 1.

The total welfare of society in the NN model is defined as the sum of the total utility, profits from CP1, and profits from the ISP:

$$W^{NN} = \frac{7}{32\alpha}.$$

Similarly, the total welfare of society in equilibrium is the sum of the total utility in the good 1 and good 2 markets, the profits for CP1 and CP2, and the profits of the ISP:

$$W^{3N} = \frac{\alpha(28\alpha^2 + \alpha - 4)}{8(4\alpha-1)^2} .$$

To compare the total welfare in each model, we prove that $W^{NN} < W^{3N}$, by substitution to show

$$\frac{7}{32\alpha} < \frac{\alpha(28\alpha^2 + \alpha - 4)}{8(4\alpha - 1)^2}, \text{ or}$$

$$7 < 2\alpha(56\alpha^3 + 2\alpha^2 - 53\alpha + 28).$$

Since the total utility, profits of CPs, and the profits of ISPs are all greater in the NNN model compared to that in the NN model, the total welfare in the NNN model would be greater as a result.

2.3.1 Comparative Statics

Table 3 shows the total utility and total welfare under the NN case and NNN case in respect to an increase of α, the extra value consumers have on good 1 over good 2.

Table 3: Comparative Statics with respect to α[13]

U_1^{NN}	U_1^{3N}	U_2^{3N}	W^{NN}	W^{3N}
+	+	-	+	+

Proposition 5. *As the customer's value of good 1 over good 2 increases. the total utility from buying good 1 increase under net neutrality and non-net neutrality, while the total utility from buying good 2 decreases in the NNN model.*

In the NN case, as the consumer places more value on good one, he or she will be more satisfied from buying good one. Recall that a change in α has no effect on the total quantity demanded in the NN model. As a result, an increase in an individual's utility results in an increase in the total utility in the good 1 market. Meanwhile, recall that the quantity demanded for good 2 decreases with an increase of α in the NNN model. As consumers place more value on good 1, the opportunity cost of not buying good 1 also increases; it costs the consumer more

[13] See Appendix A for derivation results.

to purchase good 2. Thus, the combination of the decrease in demand for good 2 and the increased opportunity costs results in a decrease in total utility from buying good 2. Although the quantity demanded for good 1 also decrease with an increase of α, the value effect is greater than the quantity effect because the total utility from buying good 1 increase as α increases.

Proposition 6. *As the customer's value of good 1 over good 2 increases, the social welfare in society increase under net neutrality and non-net neutrality.*

In the case of the NN model, recall that the profits of the CP_1, the profits of the ISP, and the total utility all increase with an increase of α. As a result, their sum would also increase with an increase of α. In the case of the NNN model, with an increase of α, all the profits of the CP's, the profits of the ISP, and the total utility from buying good 1 increase, with the exception of a decrease in total utility from good 2. Given that

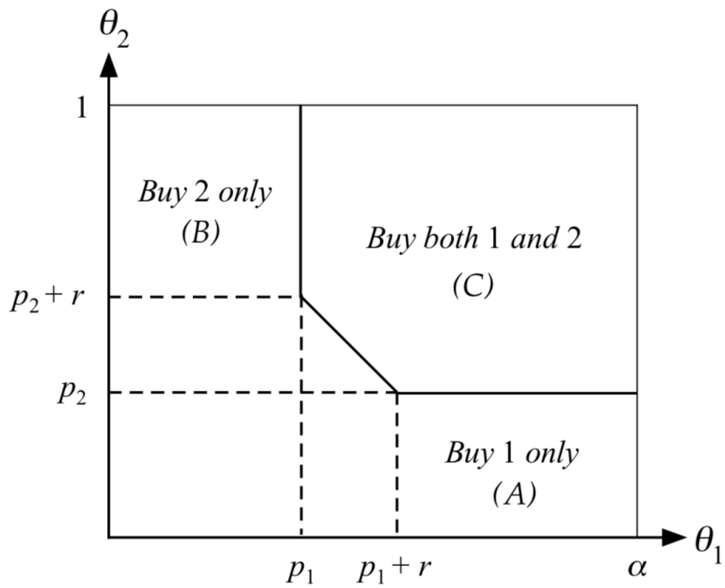
$$\frac{\partial U_2^{3N}}{\partial \alpha} < \frac{\partial U_1^{3N}}{\partial \alpha} + \frac{\partial \pi_1^{3N}}{\partial \alpha} + \frac{\partial \pi_2^{3N}}{\partial \alpha} + \frac{\partial \pi_i^{3N}}{\partial \alpha},$$

we know that the total welfare in society in the NNN model will increase as consumers value good 1 more compared to good 2.

3. Model 2

In the previous models, consumers can only buy either good 1 or good 2. Here, we expand our model by allowing the consumers to purchase both goods. A consumer has two *θ's, θ_1 and θ_2*, that represents his or her value on good 1 and good 2, respectively. Figure 4 illustrates all the possible *θ_1 and θ_2* combinations that a consumer can have. We normalize $\theta_1 \in [0,1]$, and $\theta_2 \in [0,\alpha]$, where $\alpha > 1$ because we assume consumers value good 1 more than good 2. Again, we normalize the population, $N = 1$.

Figure 5: Graph of Consumer's Value of Good 1 and Good 2 [14]



Notice that consumers with (θ_1, θ_2) in area A, will gain the most consumer surplus by buying only buy good 1. Consumers with (θ_1, θ_2) in area B will gain the most consumer surplus by buying only buy good 2. Consumers with (θ_1, θ_2) in area C will gain the most consumer surplus by buying both goods. Thus, the consumer's utility is described as

$u_1 = \theta_1 - p_1 - r$ if he or she buys good 1,

$u_2 = \theta_2 - p_2 - r$ if he or she buys good 2,

$u_3 = \theta_1 + \theta_2 - p_1 - p_2 - r$ if he or she buys good 1 or good 2,

$u_0 = 0$ if he or she does not buy.

The quantity demand for good 1 is the sum of area A and area C, which can be rewritten as

$$q_1 = \frac{1}{\alpha}(\alpha - p_1 - rp_2 - \frac{r^2}{2}).$$

[14] See Appendix B to find the calculations of the area A, area B, and area C.

Similarly, the quantity demand for good 2 is the sum of area B and area C, which can be rewritten as

$$q_2 = \frac{1}{\alpha}(\alpha - \alpha p_2 - rp_1 - \frac{r^2}{2}).$$

In both demand functions, we multiply by $1/\alpha$ in order to normalize the total area to 1. For simplicity, we run a simulation for this model by setting $\alpha = 3/2$. The demands now become

$$q_1 = \frac{3 - 2p_1 - r(2p_2 + r)}{3}, \quad q_2 = \frac{3 - 3p_2 - r(2p_1 + r)}{3}.$$

3.1 Net Neutrality (NN)

The profit functions[15] for each CP is $\pi_1 = p_1 q_1$ and $\pi_2 = p_2 q_2$. Substituting in the demand functions we get

$$\pi_1 = \frac{p_1\left[3 - 2p_1 - r(2p_2 + r)\right]}{3}, \quad \pi_2 = \frac{p_2\left[3 - 3p_2 - r(2p_1 + r)\right]}{3}.$$

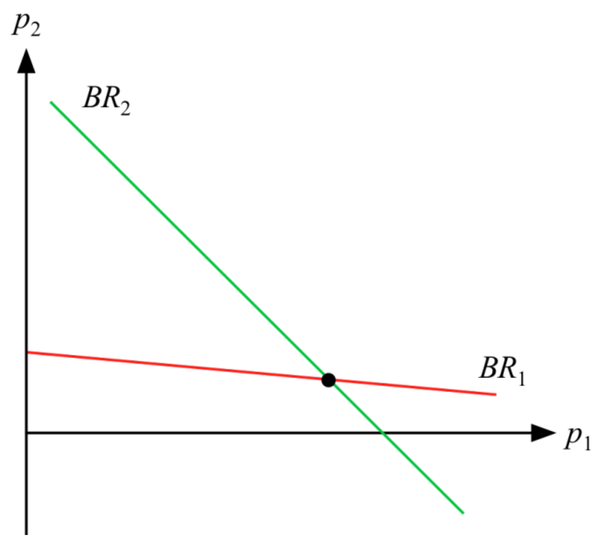
Maximizing both each profit functions, the best-response functions are

$$p_1 = \frac{-r}{2}p_2 + \frac{3 - r^2}{4}, \quad p_2 = \frac{-r}{3}p_1 + \frac{3 - r^2}{6}.$$

The best responses for the CPs are strategic substitutes. As the price of one good increase, the price of the other decreases as a result. For example, if the price of good 1 increases, this shrinks the demand of good 2 and leads to a lower price of good 2. Notice that the slope of BR2 is steeper than BR1, denoting that BR2 is more sensitive to price changes.

[15] For the profit functions of the CPs, the first order conditions holds and second order condition is negative, ensuring a maximum.

Figure 6: Best Responses for CP_1 (BR_1) and CP_2 (BR_2) [16]



Solving simultaneously for the Nash equilibrium, the optimal prices are

$$p_1^* = \frac{r(r^2 - 3r - 3) + 9}{2(6 - r^2)},\ p_2^* = \frac{r(r-3)(r+1) + 6}{2(6 - r^2)}.$$

Substituting in the optimal prices into the demand functions, the optimal *q*'s* are

$$q_1^* = \frac{r(r^2 - 3r - 3) + 9}{3(6 - r^2)},\ q_2^* = \frac{r(r-3)(r+1) + 6}{2(6 - r^2)}.$$

Meanwhile, the total number of Internet users, *i,* are denoted by the sum of area A, area B, and area C in Figure 4. The ISP's profit function[17] under NN is then $\pi_i = ri^*$, where

$$i^* = \frac{3 - 2p_1^* p_2^* - r(2p_1^* + 2p_2^* + r)}{3}.$$

Substituting for *i** yields,

[16] In the graph, we replaced *r* with *r** in the best response functions.
[17] For the profit functions of the ISP, the first order conditions holds and the Hessian matrix is negative definite and the determinant is positive, ensuring a maximum.

$$\pi_i = \frac{r(r^6 - 5r^5 - 6r^4 + 60r^3 - 45r^2 - 135r + 162)}{6(r^2 - 6)^2}.$$

Maximizing profits with respect to *r*, the optimal rate the ISP's Internet subscription fees for consumers is

$$r^* = 0.7031.$$

Replacing *r* with *r** in the prices and demand functions, then

$$p_1^* = 0.5227, p_2^* = 0.2951,$$

$$q_1^* = 0.3484, \ q_2^* = 0.2951.$$

The profits at equilibrium of CP1, CP2, and the ISP are

$$\pi_1^* = 0.1821, \ \pi_2^* = 0.0871, \ \pi_i^* = 0.2545,$$

respectively.

3.1.1 Comparative Statics

Figure 4: Comparative Statics with respect to α[18]

r^*	p_1^*	p_2^*	q_1^*	q_2^*	Q^*	π_1^*	π_2^*	π_i^*
+	+	-	+	-	+	+	-	+

Proposition 7. *The profits of CP_1 increase as the customer's value of good 1 over good 2 increases.*

At equilibrium, the price and quantity demand of good 1 increase as α increases. Recall that the two firms' best responses are strategic substitutes, and notice that as the price of good 2

[18] See Appendix B for derivations results.

falls, CP_1 responds with an increase of the price of good 1. In the quantity demand function for good 1, even though consumers need to pay a higher price for good 1, the increase of the value they have for good is greater. As a result, they are willing to buy more at a higher price. Since the profit function for CP_1 is price times demand, an increase in both variables results in an increase in profits.

Proposition 8. *The profits of CP_2 decrease as the customer's value of good 1 over good 2 increases.*

At equilibrium, the price and quantity demand of good 2 decrease as α increases. Recall that the two firms' best responses are strategic substitutes, and notice that as the price of good 1 rises, CP_2 responds with a decrease of the price of good 2. As consumers value less of good 2 compared to good 1 and thus will buy less of good 2, CP_2 decreases its price to reflect the loss of demand. Since the profit function for CP_1 is price times demand, an increase in both variables results in an increase in profits.

Proposition 9. *The profits of ISP increase as the customer's value of good 1 over good 2 increases.*

The ISP charges consumers a fee for Internet access. The total demand for both goods increase suggests that the gain in demand of good 1 is greater that the loss in demand of good 2. This surplus in the total demand reveals that there are more Internet users as consumers value good 1 more. As a result, as total demand increases, consumers are willing to buy a higher Internet fee in order to buy their goods online. Both an increase in fees charged and Internet users drive the increase in profits of the ISP.

3.2 Non-Net Neutrality (NNN)

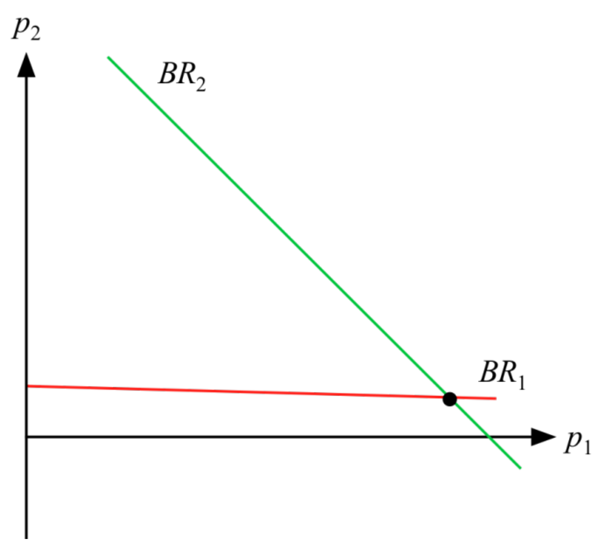
The CPs under NN face profit functions[19] of $\pi_1 = (p_1\text{-}s)q_1$ and $\pi_2 = p_2q_2$. CP1 is charged with a fee from the ISP based on the demand from the consumers. Replacing the quantity demanded in the profit functions,

$$\pi_1 = \frac{(p_1 - s)\left[3 - 2p_1 - r(2p_2 + r)\right]}{3},\ \pi_2 = \frac{p_2\left[3 - 3p_2 - r(2p_1 + r)\right]}{3}.$$

The best responses for each firm as they try to maximize their profits are

$$p_1 = \frac{3 - r^2 + 2s}{4} - \frac{r}{2}p_2,\ p_2 = \frac{3 - r^2}{6} - \frac{r}{3}p_1.$$

Figure 7: Best Responses for CP_1 (BR_1) and CP_2 (BR_2)



Again, the two firms are strategic substitutes. As one firm increases its prices, the other decreases. The Nash equilibrium prices are

[19] For the profit functions of the ISP, the first order conditions holds and the second order conditions are negative, ensuring a maximum.

$$p_1^* = \frac{r(r^2 - 3r - 3) - 6s + 9}{2(6 - r^2)}, \ p_2^* = \frac{r(r-3)(r+1) - 2rs + 6}{2(6 - r^2)}.$$

At these prices, the consumer demands for each good are

$$q_1 = \frac{3 - 2p_1 - r(2p_2 + r)}{3}, \ q_2 = \frac{3 - 3p_2 - r(2p_1 + r)}{3}.$$

The ISP profits[20] is described as $\pi_i = ri + sq_1$, or

$$\pi_i = r\left(\frac{3 - 2p_1^* p_2^* - r(2p_1^* + 2p_2^* + r)}{3}\right) + s\left(\frac{r(r^2 - 3r - 3) - 6s + 9}{3(6 - r^2)}\right).$$

Maximizing the ISP with respect to r and s and solving simultaneously for r*and s* results in

$$r^* = 0.4571, \ s^* = 0.4912.$$

Then replacing r with r* and s with s* in the prices and demand functions, we get

$$p_1^* = 0.8973, p_2^* = 0.3330,$$

$$q_1^* = 0.2507, q_2^* = 0.3330.$$

Similarly, the profits at the equilibrium are

$$\pi_1^* = 0.0942, \ \pi_2^* = 0.1109, \ \pi_i^* = 0.2932.$$

[20] For the profit function of the ISP, the first order conditions holds and the Hessian matrix is negative definite and the determinant is positive, ensuring a maximum.

3.2.1 Comparative Statics

Table 5: Comparative Statics with respect to α[21]

r^*	s^*	p_1^*	p_2^*	q_1^*	q_2^*	Q^*	π_1^*	π_2^*	π_i^*
+	+	+	-	-	-	-	+	-	+

Proposition 10. *The profits of CP_1 increase as the customer's value of good 1 over good 2 increases.*

At equilibrium, the price and quantity demand of good 1 increase as α increases. Recall that the two firms' best responses are strategic substitutes, and notice that as the price of good 2 falls, CP_1 responds with an increase of the price of good 1. In the quantity demand function for good 1, even though there is fall of prices in good 2, the increase in Internet fees and the higher prices of good 1 discourages consumers to buy less of good 1, effectively decreasing the demand. Since the profit function for CP_1 is price times demand, we know that the price effect is stronger than the quantity effect because profits increase.

Proposition 11. *The profits of CP_2 decrease as the value the consumer places on good 1 increases.*

At equilibrium, the price and quantity demand of good 2 decrease as α increases. Recall that the two firms' best responses are strategic substitutes, and notice that as the price of good 1 rises, CP_2 responds with a decrease of the price of good 2. As consumers value less of good 2 compared to good 1 and thus will buy less of good 2, CP_2 decreases its price to reflect the loss of demand. Since the profit function for CP_1 is price times demand, an increase in both variables results in an increase in profits.

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[21] See Appendix B for numerical results of the derivations with respect to α.

Proposition 12. *The profits of ISP increase as the customer's value of good 1 over good 2 increases.*

The ISP charges consumers a fee for Internet access. The total demand for both goods decrease because there are losses in the demand of good 1 and good 2. This loss in the total demand reveals that there are less Internet users as consumers value good 1 more. As a result, because of a buy a higher Internet fee, consumers are less likely to purchase access to Internet for goods, despite an increase of value in good 1. Similarly, the Internet fee charged to the CP also affects the price of good 1, which ultimately affects the demands for both goods. As s^* rises, consumers are less likely to purchase Internet access because of higher costs. However, since the final effect to the ISP is an increase in its profits, the price effect is stronger than the quantity effect.

3.3 Welfare Comparisons

Table 6: Comparison of Variables in Equilibrium under NN and NNN

	NN	NNN			NN	NNN
r^*	0.7031	0.4571		π_1^*	0.1821	0.0943
s^*	-	0.4912		π_2^*	0.0871	0.1109
p_1^*	0.5527	0.8673		Π_{cp}	0.2692	0.2052
$p_1^*+r^*$	1.226	1.324		π_i^*	0.2454	0.2932
p_2^*	0.2951	0.3304		u_1	0.0131	0.0089
$p_2^*+r^*$	0.9982	.7901		u_2	3.056×10^{-7}	0.0049
q_1^*	0.3484	0.2507		u_3	0.0680	0.0432
q_2^*	0.2951	0.3304		U	0.0811	0.0570
Q^*	0.6435	0.5811		W	0.5957	0.5554

In the NN model, total demand is $Q^{NN}=q_1^{NN}+q_2^{NN}$ .In the NNN model, total demand is $Q^{3N}=q_1^{3N}+q_2^{3N}$. Comparing $Q^{NN}>Q^{3N}$, we substitute in the demand functions at the equilibrium and get

$$0.6411 > 0.5811.$$

Under NNN model, notice that the quantity demanded for good 1 decrease, while the quantity demanded for good 2 increases, compared to the NN model. However, since the total demand decreases in the NNN model, we know that charging CP_1 a fee has a negative overall effect on social welfare as less of the population use Internet. The price of good 1 decreases because of the added fee that CP_1 pays. The fee is then passed down to through the price and discourages consumers to buy good 1. Notice that the total cost for the user for buying good 2 only, $p_2^*+r^*$, is less under NNN than NN. If we compare $\boldsymbol{p_2^{NN}+r^{NN}} < \boldsymbol{p_2^{3N}+r^{3N}}$, we see that

$$0.9982 > 0.7901.$$

The consumers are now more attracted to good 2 because of the lower total costs of price and Internet fees. However, the increased demand in good 2 does not outweigh the decreased demand in good 1.

The driving force of the decrease total demand directly affects the total profits of the CP's as well. $\prod_{cp}^{NN}=\pi_1^{NN}+\pi_2^{NN}$ represents the total CP profits in the NN model, and $\prod_{cp}^{3N}=\pi_1^{3N}+\pi_2^{3N}$ represents the total CP's profits in the NNN model. Again we show that $\prod_{cp}^{NN}>\prod_{cp}^{3N}$ through substitution of the profits at equilibrium:

$$0.2692 > 0.2052.$$

The total CP profits is less in the NNN than that of the NN model. Although CP_2's profits increases because of the increase in demand and prices, its positive effects cannot outweigh the larger negative effect in CP_1's loss in profits; thus, the total CPs' profits decreaase under NNN compared to that under NN. This results suggest that if the ISP price discriminates a more popular (denoted by α) website such as Netflix by charging it a fee, the society is worse off despite the personal gain of the less popular website.

Meanwhile, in equilibrium, the ISP's profit is $\prod_i^{NN} = \pi_i^{NN}$ in the NN and $\prod_i^{3N} = \pi_i^{3N}$ in the NNN model. We prove that $\prod_i^{NN} < \prod_i^{3N}$ by substituting the profits, and we get

$$0.2454 < 0.2932.$$

Recall the ISP's profit function is $\pi_i = ri + sq_1$. We know that the number of Internet users decreases because of the decrease of total demand. Notice that the fee it charges consumers for Internet access, r^*, also decreases significantly. These losses indicate that the ISP increases its profits through the introduction of the CP fee. The price effect of s^* overwhelms the demand effect and the price effect of r^*. The gain in profits has a positive effect on social welfare.

Similarly, the total utility in each case is $U = u_1 + u_2 + u_3$, which is the sum of consumer's utility buying good 1, good 2, and both goods.[22] First, we compare the utility from buying only good 1 under NN and NNN such that $u_1^{NN} > u_1^{3N}$. Replacing the variables with their numerical value, we see that

$$0.0131 > 0.0089l.$$

Recall from the utility function of good 1, lower prices and lower Internet fees increases utility for each consumer. Although the Internet fee is lower under NNN, the increase of in price is larger compared the price under NN, and thus decreases the overall utility from good 1. On the contrary, we have $u_2^{NN} > u_2^{3N}$ such that

$$3.056 \text{ x } 10^{-7} < 0.0049.$$

[22] See Appendix B for functions of integrals to find the consumers' total utility.

The same economic intuition is applied for this difference in utility from buying good 2. Under NNN, the increase in price of good 2 lowers utility, but the larger decrease in Internet fee ultimately has an overall positive effect on utility. Finally, since the consumer's utility from buying both goods decreases if prices and fees go up. We see that the combined increase in prices of good 1 and good 2 outweigh the benefits from lower Internet fees in NNN, which results in the decrease of utility of the consumer buying both goods. Hence, we have $u_3^{NN} > u_3^{3N}$, or

$$0.5957 > 0.5554.$$

When we combine all the changes of all three types of utility, the total utility decreases under NNN. Furthermore, the increase in total demand means that more people in the population are participating in the market. The consumers who had a utility of 0 from buying no goods now receives positive utility from buying. These changes suggest that total utility of consumers has a negative on social welfare when going from NN to NNN.

The total welfare of society in the NN model is defined as the sum of the total profits from the two CPs, profits from the ISP, and the total utility:

$$W^{NN} = \prod_{cp}^{NN} + \pi_i^{NN} + U^{NN} = 0.5957.$$

Similarly, the total welfare of society in equilibrium is the sum the profits of CP_1 and CP_2, and the profits of the ISP:

$$W^{3N} = \prod_{cp}^{3N} + \pi_i^{3N} + U^{3N} = 0.5554.$$

Clearly,

$$0.5957 > 0.5554.$$

Although the profits of ISPs and CP_1 are greater in the NNN model compared to that in the NN model, the total social welfare decreases because of greater losses in CP_2's profits and total utility of the consumers.

3.3.1 Comparative Statics

Table 7: Comparative Statics with respect to α[23]

	u_1^{NN}	u_2^{NN}	u_3^{NN}	U^{NN}	u_1^{NNN}	u_2^{NNN}	u_3^{NNN}	U^{NNN}	W^{NN}	W^{3N}
α	+	?	?	+	+	-	-	?	+	+

Proposition 13. *As the customer's value of good 1 over good 2 increases, the total welfare in society increases under net neutrality.*

Recall from Figure 5 that an increase in α indicates an increase of the upper limit of θ_1. In the NN model, the utility from buying only good 1 increases because now more consumers enter the good 1 market, since they value the good more. Yet, the effect on the utility from buying only good 2 is ambiguous because a change in α can increase or decrease the utility from good 2 depending on the value of α. The same effect applies for the change in utility from buying both goods. However, the absolute value of the changes in the sum of utility from good 2 only and from both goods is less than the increase in utility from good 1 only, because we see that the total utility in the model under NN increases as α increases.

Proposition 14. *As the customer's value of good 1 over good 2 increases, the change in total welfare in society is ambiguous under non-net neutrality.*

Under NNN, the utility from good 1 only increases as α increases. Again, the increase of the upper limit of θ_1 yields in a larger market for good 1 only. Meanwhile, notice that the utility

[23] See Appendix B for numerical results of the derivations with respect to α.

from good 2 only and the utility from both goods decrease under the same condition. Despite the decrease in price of good 2, the increase in Internet fees as α increases is the main reason for the decrease in utility. However, the change in total utility is ambiguous. If $\frac{\partial u_1^{3N}}{\partial \alpha} < \left| \frac{\partial u_1^{3N}}{\partial \alpha} + \frac{\partial u_1^{3N}}{\partial \alpha} \right|$, then the total utility will decrease when α increases. Conversely, if $\frac{\partial u_1^{3N}}{\partial \alpha} > \left| \frac{\partial u_1^{3N}}{\partial \alpha} + \frac{\partial u_1^{3N}}{\partial \alpha} \right|$, then the total utility will increase when α increases.

Proposition 15. *As the customer's value of good 1 over good 2 increases, the total welfare in society increases under NN and non-net neutrality.*

Recall that in both model, as α increases, the profits for CP_1 and ISP increases while CP_2's profits decrease. Because we know that the social welfare increases, the effects of CP_1 and ISP are greater than the effect of CP_2.

4 Conclusion

My two models produced contrasting results. In a world where consumers can only buy good 1 or good 2, NN yields a higher social welfare. The main reason for this is under net neutrality, only CP_1 can sustain positive prices for its goods, resulting in only one good. However, the market expands in the case of NN because consumers now can buy good 2 as well. The introduction of the fee on CP_1 allows CP_2 to be competitive in the market. With a wider variety of goods for consumers, a higher percentage of the population subscribes to the Internet and increases the profits for the ISP, the CPs, and the total utility.

On the other hand, in a world where consumers can buy good 1 and good 2 as well as just one of the goods, NN yields a lower social welfare. My results further support the works of pervious literature. In the case where CP_1 is charged a fee, the only winners from this scenario are the ISP and CP_2. If we assume that the ISP is vertically integrated and owns CP_2, then it has strong incentive to charge only CP_1 a fee. The CP_2 will have higher demands and profits, while the ISP will have higher profits from the fees from CP_1. However, such action decreases the social welfare when looking at society as a whole. Since consumers value good 1 over good 2, the higher prices of good 1 lead to a decrease in consumption of the goods. The losses in total utility of the consumers and in profits of CP1 are larger than the gains from CP_2 and the ISP, leading society to be worse off.

Further research from my paper includes the exploration of the effects of social welfare when the ISP charges both CPs instead of one. This would eliminate discrimination in the model by the ISP and only focuses on the effects of whether the ISP should charge a fee to all the CPs. Another extension includes changing the profit functions of the CPs. Currently, the CPs in my models gain revenues from charging a subscription fee to its consumer to access their contents. However, many CPs obtain revenues primarily from advertisements. Lastly, perhaps a more complex model which includes differential pricing on the consumer side as well as the CP side, can be designed to look at a larger picture of the Internet structure. The effects of investments in cyberspace or negative externalities such as congestion effects can be added to the model. For example, charging a CP a fee based on the amount of congestion effect it has from bandwidth usage may alter the social welfare.

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Appendix A: Model 1

Note: All calculations are done with functions at equilibrium.

Net Neutrality

The comparative statics functions of each variable are as follows:

$$\frac{\partial p_1^*}{\partial \alpha} = \frac{1}{4}, \quad \frac{\partial q_1^*}{\partial \alpha} = 0, \quad \frac{\partial r^*}{\partial \alpha} = \frac{1}{2},$$

$$\frac{\partial \pi_1^*}{\partial \alpha} = \frac{1}{16}, \quad \frac{\partial \pi_i^*}{\partial \alpha} = \frac{1}{8},$$

$$\frac{\partial U_1^{NN}}{\partial \alpha} = \frac{1}{32}, \quad \frac{\partial W^{NN}}{\partial \alpha} = \frac{7}{32}.$$

The integral of the total utility from good 1 is

$$U_1^{NN} = \int_{\theta_n^*}^{1} (\alpha\theta - p_1^* - r^*)\partial\theta, \text{ where}$$

$$\theta_n^* = \frac{p_1^* - r^*}{\alpha}.$$

Non-Net Neutrality

The comparative statics functions of each variable are as follows:

$$\frac{\partial r^*}{\partial \alpha} = 0, \quad \frac{\partial s^*}{\partial \alpha} = \frac{1}{2},$$

$$\frac{\partial p_1^*}{\partial \alpha} = \frac{3}{2}\left(\frac{8\alpha^2 - 4\alpha + 1}{(4\alpha - 1)^2}\right), \quad \frac{\partial p_2^*}{\partial \alpha} = \frac{3}{2(4\alpha - 1)^2},$$

$$\frac{\partial q_1^*}{\partial \alpha} = \frac{-1}{(4\alpha - 1)^2}, \quad \frac{\partial q_2^*}{\partial \alpha} = \frac{-1}{2(4\alpha - 1)^2}, \quad \frac{\partial Q^*}{\partial \alpha} = \frac{-3}{2(4\alpha - 1)^2},$$

$$\frac{\partial \pi_1^*}{\partial \alpha} = \frac{1}{2}\left(\frac{24\alpha^3 - 18\alpha^2 + 10\alpha + 8\alpha s - 1 - 2s}{(4\alpha - 1)^3}\right), \quad \frac{\partial \pi_2^*}{\partial \alpha} = \frac{1}{4}\left(\frac{2\alpha + 1}{(4\alpha - 1)^3}\right),$$

$$\frac{\partial \pi_i^*}{\partial \alpha} = \frac{1}{4}\left(\frac{8\alpha^2 - 4\alpha - 1}{(4\alpha - 1)^2}\right),$$

$$\frac{\partial U_1^{3N}}{\partial \alpha} = \frac{\alpha}{2}\left(\frac{4\alpha^2 - 3\alpha - 2}{(4\alpha - 1)^3}\right), \quad \frac{\partial U_2^{3N}}{\partial \alpha} = \frac{-\alpha}{4(4\alpha - 1)^3}.$$

$$\frac{\partial W^{3N}}{\partial \alpha} = \frac{56\alpha^3 - 42\alpha^2 + 5\alpha + 2}{4(4\alpha - 1)^3}.$$

The integral of the total utility from the goods are

$$U_1^{3N} = \int_{\theta_h^*}^{1} (\alpha\theta - p_1^* - r^*)\partial\theta, \quad U_2^{3N} = \int_{\theta_l^*}^{\theta_h^*} (\theta - p_2^* - r^*)\partial\theta, \text{ where}$$

$$\theta_h^* = \frac{p_1^* - p_2^*}{\alpha - 1}, \ \theta_l^* = p_2^* + r.$$

Appendix B: Model 2

Note: All calculations are done with functions at equilibrium.

From Figure 5, the area of region A is calculated as

$$A = \frac{p_2^* \left(\alpha - p_1^* - r^*\right)}{\alpha}.$$

The area of region B is calculated as

$$B = \frac{p_1^* \left(1 - p_2^* - r^*\right)}{\alpha}$$

The area of region C is calculated as

$$C = \frac{1}{\alpha}\left[(\alpha - p_1^*)(1 - p_2^*) - \frac{\left(r^*\right)^2}{2} \right].$$

We normalize the areas to 1 by multiplying them by $1/\alpha$.

We calculate the total utility from good 1 only by calculating the volume under the utility of the goods plane bounded by region A, such that

$$U_1 = \frac{p_1^*}{\alpha} \int_{p_1^* + r^*}^{\alpha} (\theta_1 - p_1^* - r^*) \partial\theta_1 .$$

Similarly, we calculate the total utility from good 2 only by calculating the volume under the utility plane bounded by region B, such that

$$U_2 = \frac{p_2^*}{\alpha} \int_{p_2^* + r^*}^{1} (\theta_2 - p_2^* - r^*) \partial\theta_2 .$$

In both equations, we multiply by $1/\alpha$ to normalize our results to 1.

We calculate the total utility from both good 1 and good 2 by calculating the volume under the utility plane of buying good 1 and good 2 bounded by region C, such that

$$U_3 = \frac{1}{\alpha^2}\int_{p_1^*+r^*}^{\alpha}\int_{p_2^*}^{1}(\theta_1+\theta_2-p_1^*-p_2^*-r^*)\partial\theta_2\partial\theta_l + \frac{1}{\alpha^2}\int_{p_1^*}^{p_1^*+r^*}\int_{p_1^*+p_2^*+r^*-\theta_1^*}^{1}(\theta_1+\theta_2-p_1^*-p_2^*-r^*)\partial\theta_2\partial\theta_l.$$

We multiply by $1/\alpha^2$ to normalize our results to 1.

Net Neutrality

Table B1: Results of the Variables at Different α Values

α	**1.00**	**1.25**	**1.50**	**1.75**	**2.00**
r^*	0.5900	0.6541	0.7031	0.7414	0.7718
p_1^*	0.3189	0.4183	0.5527	0.6309	0.7421
p_2^*	0.3189	0.3050	0.2951	0.2878	0.2824
q_1^*	0.3189	0.3346	0.3484	0.3605	0.3711
q_2^*	0.3189	0.3059	0.2951	0.2878	0.2824
Q^*	0.6378	0.6405	0.6435	0.6483	0.6535
π_1^*	0.1017	0.1400	0.1821	0.2274	0.2754
π_2^*	0.1017	0.0930	0.0871	0.0828	0.0797
π_i^*	0.2053	0.2278	0.2454	0.2595	0.2709
u_1	3.122×10^{-5}	0.0053	0.0131	0.0257	0.0474
u_2	3.122×10^{-5}	0.0002	3.057×10^{-7}	7.020×10^{-5}	9.096×10^{-5}
u_3	0.0637	0.0703	0.0680	0.0675	0.0688
U	0.0637	0.0758	0.0811	0.0933	0.1163
W	0.3907	0.5366	0.5957	0.6630	0.7548

Non-Net Neutrality

Table B2: Results of the Variables at Different α Values

α	**1.00**	**1.25**	**1.50**	**1.75**	**2.00**
r^*	0.4305	0.4468	0.4571	0.4640	0.4691
s^*	0.2565	0.3720	0.4912	0.6124	0.7346
p_1^*	0.5508	0.6856	0. 8673	1.0508	1.2354
p_2^*	0.3444	0.3375	0.3304	0.3299	0.3276
q_1^*	0.2513	0.2509	0.2507	0.2505	0.2504
q_2^*	0.3444	0.3375	0.3304	0.3299	0.3276
Q^*	0.5957	0.5884	0.5811	0.5804	0.5780
π_1^*	0.0632	0.0787	0.0943	0.1098	0.1254
π_2^*	0.1186	0.1139	0.1109	0.1088	0.1073
π_i^*	0.2219	0.2583	0.2932	0.3271	0.3603
u_1	0.0001	0.0038	0.0089	0.0167	0.0270
u_2	0.0087	0.0063	0.0049	0.0040	0.0034
u_3	0.0596	0.0494	0.0432	0.0392	0.0364
U	0.0693	0.0594	0.0570	0.0598	0.0667
W	0.4728	0.5104	0.5554	0.6056	0.6598