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Honours Thesis

Toll Booths on the Internet

Adblocking and Online Media

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Declaration

I hereby declare that this submission is my own work and to the best of my knowledge it contains no material previously written by another person, or material which to a substantive extent has been accepted for the award of any other degree or diploma of a university or other institute of higher learning, except where referenced in the text.

I also declare that the intellectual content of this thesis is the product of my own work, and any assistance that I have received in preparing the project, writing the program as well as presenting the thesis, has been duly acknowledged.

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Abstract

Adblocking software allows consumers to view online content without seeing ads. However, without blocking ads it may be the case that publishers advertise too much. Paying adblockers to have ads unblocked may deliver a better outcome than both alternatives, but only if competition between adblockers is not too intense so adblockers can unblock ads without loosing too many users. Restricting how much adblockers can charge publishers can preserve incentive for content production while allowing ads to be unblocked.

Chapter 1
Introduction

Traditionally, publishers of media content such as newspapers and television channels often bundle their products with advertising and allow their products to be available for free or at a very low cost. Over the last two decades, many publishers took the opportunity created by advancements in information technologies to distribute content over the internet. However, it continues to be very common for publishers to rely on advertising as their primary generator of revenue. It is in this context that it became common for consumers to use adblocking software. Such program prevent ads from being shown on a consumer's device. A report by PageFair and Adobe (PageFair and Adobe) finds that between 2014 and 2015, the number of desktop users with adblock software installed grew by 41% to 181 million. The usage of adblock software on mobile devices is also becoming more popular. With the release of IOS9 in 2015, Apple made the decision to allow the distribution of adblocking software in the Apple Store. Google has taken a tougher stance against adblocking, removed a number of adblockers from the Play Store on the grounds that they were interfering with other apps, but dedicated adblocking browsers are still available.

The pressure of lost revenue from adblocking had led to deals being struck between developers of popular adblocking software, online publishers and advertisers to unblock a limited amount of advertising, shown to the users of the software. This practice became known as "whitelisting" an ad. However, adblock companies, notably Eyeo, developer of the web extension Adblock Plus, had been criticised for profiting by demanding payments from publishers to add their ads to an adblock whitelist. The publisher Axel Springer brought a court case against Eyeo in Germany under German competition law, where in June 2015 the courts ruled that charging Axel Springer for whitelisting their ads is illegal.

In this thesis, I look at how adblocking affect the welfare of consumers and publishers. I analyse how adblockers decide the amount of ads to whitelist and how publishers may respond to the introduction of adblocking. I also examine the claim that adblockers holds significant power over content providers regarding whitelisting ads. I find that adblockers do not compete against each other to sell access of consumers to publishers. Instead, the intensity of competition between adblockers determine the number of ads whitelisted. Adblocking can enhance social welfare through benefiting consumers if enough ads are being whitelisted to fund content production. However, if competition between adblockers is intense, few ads are whitelisted and social welfare is reduced due to low level of content production.

The analysis I present is applicable to not only publishers but also other firms based on online advertising. For example, social media platforms such as Facebook allow users to create and view content generated by other users. Content Aggregator such as Google provide users with content produced around the web. Finally, platforms for independent publishers such as Youtube pays professionals to produce content consumers can access on the platform, but are not explicitly publishers themselves. These firms differs from a traditional publisher in that they do not produce media content as a publisher might. Instead, they develop a platform where users can access content, and the content available on the platform is provided by external sources. Therefore, we can think that these firms chooses the amount of content they offer to consumers indirectly through the firm's investment decisions. I'll refers to all of these firms as well as publisher collectively as content providers.

Some parallels can be drawn between my model and that of Armstrong (2006). In Armstrong's paper, a platform allows 2 types of agents to interact with each other. After paying an entry fee, an agent of one type gains a benefit through interacting with an agent of the other type. One variant of the model Armstrong considers is the case where 2 platforms engage in intense competition, and that the 2 types of agents differs such that one type of agents can choose to use only one platform (single-homing) while the other type of agents can choose to use both platforms at the same time (muti-homing). Because of this, platforms do not need to compete with each other for type 2 agents's presence in their platform. As such, the equilibrium is that the price platforms charges type 2 consumers maximises the joint welfare of the platform and type 1 consumers without regard to the welfare of type 2 consumers.

In my model, the relationship between an adblocker and a content provider is similar to the platform and muti-homing agents in Armstrong (2006), such that adblockers always hold monopoly access to consumers. My model differs from Armstrong (2006) in that consumers can consume content produced by the content provider even if the content provider did not enter into agreement with an adblocker. Since consumers' incentive is to see as few ads as possible, competition between adblockers drives the number of ads whitelisted down, such that it falls below the level of ads which maximises the joint welfare of the platform and consumers.

Although adblockers demanding payment for whitelisting ads on the internet is a recent development, the impact of how consumers avoiding ads affects economic outcomes has been studied by a number of authors. These models are typically driven by the assumption that consumers dislikes ads and seeing ads is part of the price a consumer pays to access content, such as in Anderson and Gans (2011) and Stuhmeier and Wenzel (2011). Tag (2009) looked at how firms choose between a subscription model or an advertising model based on the assumption that seeing ads is costly to the consumer. Empirical evidence also supports this hypothesis. Using data from 6 US television networks, Wilbur (2008) estimated that a decrease of ad levels by 10% increases audience size by 25%.

Recent work on sender-receiver models provides a theoretical justification for why consumers dislike ads. These models focus on how firms can impose externalities on consumers by sending too many ads. Some papers on the topic are Van Zandt (2004), Anderson and de Palma (2009) and Johnson (2013).

Van Zandt (2004) analyses advertising in a sender-receiver model, where firms choose how many messages to send to consumers, and consumers are given a fixed capacity in the number of messages he can process. The firm pays a cost for each message sent. If a consumer receives more messages then he can process then each message is processed with a probability. For each message, there is a probability where the consumer will benefit if he responds, and so if a message is processed and the consumer benefits, the consumer responds to the message. If the consumer responds, a surplus is generated for the firm. Van Zandt shows that in equilibrium, firms sends too many messages when the cost of communication is low, and useful messages are lost amongst large number of low quality messages.

Anderson and de Palma (2009) expands on Van Zandt (2004) by allowing consumers to choose an attention span. Firms choose the number of consumers to advertise to and pay a transmission cost for each message sent. Consumers pay a cost for each message examined and choose an attention span based on expected payoff of each message. Anderson and de Palma (2009) shows that when the number of message received exceed the consumers attention span, a small tax on transmission strictly benefits all consumers and increases gross firm surplus. If a nuisance cost for each message a consumer receives is introduced, consumers may prefer to block all messages depending on the size of the cost.

Johnson (2013) considers a model where firms choose the number of consumers to advertise to and consumers can choose to block ads at a cost. Firms pay a cost for each message sent and each ad the consumer receives imposes a nuisance cost on the consumer. If a consumer responds to advertising, both the firm and the consumer gain a fixed amount of surplus. Johnson shows that if a firm's surplus relative to its costs is greater than a consumer's surplus relative to his cost, a reduction in the volume of advertising from equilibrium levels raises social welfare. The consumer's decision to block ads depends on the cost of blocking ads relative to the volume of ads being sent.

In terms of subject matter, Anderson and Gans (2011) is the most similar to my analysis. Anderson and Gans explicitly model advertising avoidance technology (AAT) as an option that consumers can choose to use at a cost, where AAT refers to technologies such as digital video recorders as well as adblock software. The key difference in our approach is that Anderson and Gans (2011) focuses on the impact of AATs on the behaviour of a publisher. They found that the introduction of AAT would lead to publishers choosing to produce more mainstream content rather than niche content, and that publishers would raise ad levels. In this paper, I abstract away much of the content provider's behaviour to focus on the impact of allowing adblockers to whitelist ads.

Chapter 2
Advertising Funded Content Production

First, I'll consider a model where consumers without adblockers access content produced by an advertising funded content provider at no cost. I'll then compare the outcomes with a model where consumers have access to an adblocker in the following chapter.

2.1 Content Providers and Consumers

A monopolist content provider decides the amount of content to produce, denoted q_p, with $q_p \geq 0$. The content provider faces a quadratic cost function for producing content, $\frac{1}{2}q^2$. The content provider choose the level of advertising a, $0 \leq a \leq A$, to be bundled with each unit of content a consumer sees, where A is a large number. The content provider is given revenue r, $r > 0$, for each unit mass of ads a unit mass of consumer sees. We can think that the content provider is small compared the market for advertising, such that changes in the output of the content provider does not affect the market price of an ad.

There are a number of reasons why an advertising model is more profitable for a content provider than a directly charging consumers. Firstly, it may be that the content provider is targeting a large audience each with individually low valuation of the content. In that case, the act of charging might produce enough friction to stop a large amount of consumers from accessing the content. Secondly, it may be that advertisers are willing to pay more to have their message reach consumers than consumers are willing to pay for content. In both cases, if advertising were to become less profitable, some content may never be produced while others may switch to charging consumers directly. For simplicity, I do not allow content providers to charge consumers.

A unit mass of consumers choose how much content to consume, q_c, between 0 and all the content produced by the content provider, $0 \leq q_c \leq q_p$. Content is a non-rival good - once a unit of content is produced, all consumers can access the unit of content. Consumers gain a benefit of $b > 0$ for each unit of content they consume, and they pay a nuisance cost of $c > 0$ for each ad they see.

2.2 Timing

The timing of the game is as follows

1. Content provider chooses the amount of content to produce q_p and the level of advertising bundled with each unit of content a.

2. Consumers choose how much content to consume, q_c.

By letting the consumer move last, the content provider's choice of the level of advertising must take into account of how consumers react to advertising.

2.3 Profit and Utility Functions

The profit function of the content provider is

$$\pi_p = a\,r\,q_c - \frac{1}{2}q_p^2$$

This equation describes the profit of the publisher, which is the ad revenue minus the production costs.

The utility function of a consumer is

$$U = q_c(b - ca)$$

This equation describes how for each unit of content a consumer consumes, he gains a benefit of b and pays a nuisance cost of a.

2.4 First Best

In the first best case, a social planner who's objective is to maximise total surplus chooses the level of advertising a, quantity of content produced q_p and consumed q_c. The total surplus function, which is the sum of consumer utility and content provider profits, can be written as:

$$S = a\,r\,q_c - \frac{1}{2}q_p^2 + q_c(b - ca)$$

We can think of this this total surplus function as social welfare if we suppose r represents all the surplus gained by the advertiser from the consumer seeing the ad.

Then taking the derivative of the total surplus function with respect to the level of advertising a, we find that the first best level of advertising is

$$a^{fb} = \begin{cases} A & \text{if } r > c \\ 0 & \text{if } r < c \end{cases}$$

Proposition 1: The first best choice of level of advertising is therefore A when it's a net benefit and 0 when it's a net harm.

We have taken r as a constant by assuming that the content provider is a small player in the market for advertising, which is why we have arrived at a boundary solution here. When $r > c$, the revenue the content provider receives exceeds the nuisance cost a consumer pays from an additional ad, therefore we want to show consumers as many ads as possible. The opposite is true when $r < c$. We can think that advertising to society is a net benefit when $r > c$, and a net harm when $r < c$.

In sender-receiver models we see that while not all advertising is harmful to society, senders have incentive to advertise too much such that the marginal ad reduces total surplus (Anderson and de Palma 2009). However, since our content provider is small and does not affect the market for advertising, the marginal ad reducing social welfare would correspond with the case where $r < c$.

Now let's consider the first best level of content production. First, notice that when $q_p > q_c$, an increase in q_c strictly increase total surplus. Because consumers cannot consume more content then content providers produces ($q_c \leq q_p$), to maximise total surplus we must have $q = q_p = q_c$.

The first best level of content produced and consumed is

$$q^{fb} = a^{fb}(r - c) + b$$

The first term is the amount of content produced where the content is a vehicle for delivering advertising. When $r > c$, an increase in the level of advertising taking everything else constant increases total surplus. Since cost of content production is increasing as the amount of content produced is increasing, the first best reflects the point where the marginal cost is equal to the marginal benefit.

The second term is where the social planner considers the consumer's utility in his choice of content production. Here the content is produced for the consumption of the consumer without regards to advertising.

2.5 Equilibrium Analysis

Now let's consider the choices agents would make to maximise their private profit and utility functions. The equilibrium amount of content a consumer would choose to consume is given by

$$q_c^* = \begin{cases} q_p & \text{if } b \geq ca \\ 0 & \text{if } b < ca \end{cases}$$

What this says is that a consumer would choose to consumes all the content available if benefit b is greater than total nusiance cost ca, and that he would choose to consume no content otherwise. Therefore, we can treat $b \geq ca$ as the consumer's participation constraint.

The content provider's profit is strictly increasing with the level of advertising as long as the content provider respects the consumer's participation constraint. Therefore the profit maximising level of advertising is

$$a^* = \frac{b}{c}$$

Since the consumer would consume all content when his participation constraint is met, the content provider therefore choose $q = q_c = q_p$. The profit maximising level of content production is therefore

$$q^* = \frac{b}{c}r$$

Comparing with the equilibrium level of advertising with the first best outcome, we find that $a^* > a^{fb}$ when $r > c$ and $a^* < a^{fb}$ when $r < c$. However, this is insufficient if we want to make a statement about if the level of ads the publisher sets is too high or too low. In the first case, we must keep in mind that content is funded through advertising. In the first best, content production is independent of advertising and therefore advertising is can be judged by it's own merits. But in our model, we need advertising to fund content production and must consider the trade off of content not produced and showing ads which produce more nuisance cost then revenue. In the second case, the reason why publishers are advertising too little is because they must respect the consumer's participation constraint.

The more interesting question to ask is that if advertising is excessive in equilibrium when we consider it in the context of a second best case, where we acknowledge that content is funded through advertising and content providers must respects the consumer's participation constraint. To answer this, suppose we conduct the following thought experiment. Suppose a social planner who's objective is to maximise total surplus chooses a, and that consumers choose q_c and content providers choose q_p. As before, the timing is that in the first stage, the social planner chooses a and the content provider chooses q_p. In the second stage, consumer chooses q_c. Is the level of advertising chosen by the social planner less then that would be chosen by the publisher?

The level of ads chosen by the social planner is

$$a_s = \begin{cases} \dfrac{b}{2c - r} & \text{if } r < c \\ \dfrac{b}{c} & \text{if } r \geq c \end{cases}$$

Proposition 2: When $r < c$, a reduction in the level of advertising chosen by a content provider increases total surplus. When $r > c$, a reduction in the level of advertising chosen by a content provider reduces total surplus.

The case where $r < c$ is when the participation constraint of the consumer is non-binding. while when $r \geq c$ is when the constraint is weakly binding. Comparing to the level of ads set by the content provider, we find that in the first case, the content provider sets a level of ads that is too high, while in the second case we find the content provider would set the same level of ads as the social planner would.

Note that $r < c$ is also the condition where advertising in a net harm to society. We can therefore say that when if content production is funded through advertising, and that advertising is a net harm to society, then the level of advertising chosen by a content provider is too high even after we take into consideration of the content production that advertising made possible.

Chapter 3
Adblocking and Whitelisting

3.1 Adblockers, Competition and Revenue Sharing

Suppose there are two adblockers who supply adblocking software to consumers at zero marginal cost. Software can be duplicated at very little cost to the developer, and the bulk of the cost is paid during the development process, which is a fixed cost paid to enter the market. I ignore fixed cost for simplicity.

I model competition between adblocker using a spatial product differentiation model based on Hotelling (1929). I fix the location of the adblocker to opposite sides of a unit long Hotelling line. Adblocker 1 is located at $l_1 = 0$, and Adblocker 2 is located at $l_2 = 1$. A unit mass of consumers are distributed uniformly on the Hotelling line. Let consumer j be located on position j, $j \in [0, 1]$.

Consumers must choose to use one of the two adblockers. A consumer travels from his position on the Hotelling line to the location of the adblocker, and pay a transportation cost equals to τ, $0 \leq \tau$, multiplied by the distance traveled. The transportation cost represents how a consumer may have a preference for one adblocker over another. Factors that may cause a consumer to be reluctant to switch adblockers may be a preference for an adblocker through product characteristics such as delivery of the product, marketing, ease of use, user interface, reputation or availability on a particular internet browser. Alternatively, it may be a lack of information about the choice of adblockers and the whitelisting process rather than a deliberate choice. We can think of τ as the inverse of the intensity of competition between adblockers. If consumers have stronger preference for an adblocker, then the intensity of competition between adblockers is low. I have also forced consumers to consume all content produced, I'll elaborate on the reason and impact of this further on.

Adblockers compete for consumers over number of ads whitelisted. There are two adblockers, denoted as adblocker i, $i = 1, 2$. I assume adblockers are able to control exactly which ads their software blocks at no cost. This means adblockers choose the number of ads a consumer see with every unit of content, a_i, $0 \leq a_i \leq \frac{b}{c}$. Since I forced all consumers to consume content by assumption, the upper restriction on

a serves to emulate the consumer's participation constraint we have in our model of advertising funded content production.

The adblocker can make an offer to the content provider to enter into a revenue share scheme, where the percentage denoted μ_i, $0 \leq \mu_i \leq 1$, is given to the adblocker. This is the price an adblocker charges to whitelist ads from the content provider.

3.2 Profit and Utility functions

Suppose the number of consumers using adblocker i is z_i. The profit function of the adblocker i is therefore given by

$$\pi_i = qr\mu_i a_i z_i$$

Intuitively, the profit of an adblocker is the number of views an ad receives by users of the adblocker, $q \times a_i \times z_i$, multiplied by the share of revenue the adblocker receives from one ad being seen, $r \times \mu_i$.

The profit function of the content provider is given by

$$\pi_p = qr(1-\mu_1)a_1 z_1 + qr(1-\mu_2)a_2 z_2 - \frac{1}{2}q^2$$

That is, the profit of the content provider is the number of views an ad receives, $q \times a_i$, multiplied by share of revenue the publisher receives for consumers using both adblockers, $r(1-\mu_1)z_1 + r(1-\mu_2)z_2$, minus the cost of producing content, $\frac{1}{2}q^2$.

Finally, the utility of consumer j is given by

$$U_j = q(b - ca_i - \tau|l_i - j| + \frac{1}{4}\tau)$$

As I briefly discussed before, I have added an additional restriction that consumers must consume all content produced because it is possible for the net utility from consuming content to be negative as a result of the transportation cost. Additionally, I compensate consumers by the expected transportation cost. The goal is to have consumer surplus to behave as if consumers have a preference for each adblocker but pays no cost to use either. This allow me to compare the welfare results of the current model with the model of advertising funded content production under such a premise. The compensation is as follows. $\hat{j}$ is the marginal consumer, indifferent between adblocker 1 and 2. So long as $\hat{j} = \frac{1}{2}$, consumers are compensated the expected transportation cost, $\frac{1}{4}\tau$. $\hat{j} = \frac{1}{2}$ is true in equilibrium as well as in all the analysis I will discuss in this chapter.

Returning to the utility function, it describes that the utility of a consumer is the quantity of content consumers multiplied by the net benefit of consuming content. If we take the sum of consumer surplus, the last two terms cancels in equilibrium, leaving us with a consumer surplus as a function of quantity of content produced and level of ads, similar to what we have in our previous model of advertising funded content production.

3.3 Timing of the Game

1. Each adblocker proposes to the content provider a revenue share scheme. The content provider can accept or reject.
2. Content provider chooses q, the amount of content to produce. Simultaneously, adblockers i chooses a_i, the amount of ads users of the adblocker sees.
3. Consumers chooses which adblocker to use.

Anderson and Gans (2011) analysed advertising avoidance where consumers buy advertising avoidance technologies (AAT), which they described as including equipment such as digital video recorders as well as ad-blockers. The key results in Anderson and Gans in driven by the assumption that consumers make the purchase decision before the publisher makes decisions on content production. Here I reverse this assumption, and allow the consumer to move last to emphases the different preference consumers have for adblockers.

3.4 Equilibrium Outcome

Proposition 3: As the intensity of competition between adblockers, τ^{-1}, increase, the number of ads whitelisted a_i and content production q is decreasing. Revenue share is not affected by competition between adblockers.

The number of consumers choosing each adblocker can be calculated from the position of the marginal consumer who is indifferent between the 2 adblockers. Let the marginal consumer be denoted by $\hat{j}$. All consumer to the left of the marginal consumer prefers to use adblocker 1, and all the consumers to his right prefers adblocker 2. In equilibrium, the position of the marginal consumer is

$$\hat{j} = \frac{1}{2} + \frac{1}{2\tau}(a_2 - a_1)$$

Facing the above demand function, the symmetric equilibrium where the number of ads each adblocker i white list, a_i, is

$$a_i^* = \begin{cases} \tau & \text{if content provider accepts adblocker } i\text{'s proposal} \\ 0 & \text{if content provider rejects adblocker } i\text{'s proposal} \end{cases}$$

The amount of whitelisting a_i adblockers engage in is determined only by the intensity of competition between the adblockers τ^{-1}. Adblockers prefer to have more ads whitelisted at given a number of consumers using the adblocker, while consumers prefer to see as few ads as possible. As competition intensifies, the preferences of consumers dominates the preferences of the adblocker.

At the same time, content producers choose the amount of content q to produce. The quantity of content production chosen by the content producer is a function of revenue per ad, r, revenue share to the content producer, μ, and the level of competition between adblockers, τ^{-1}.

$$q^* = r(1 - \mu_1)\frac{\tau}{2} + r(1 - \mu_2)\frac{\tau}{2}$$

The equilibrium level of content production q^* is an increasing function of the revenue of the content provider, which depends on the level of competition between adblockers, τ^{-1}, and the revenue sharing scheme, μ.

Now consider the amount of revenue share, μ, an adblocker will demand for whitelisting ads, given the adblocker's expectation of the publisher's choice of content production.

$$\mu_i^* = 1 - \frac{1}{2}\mu_{-i}$$

The revenu share an adblocker ask for can be written as a reaction function, decreasing with amount the other adblocker asks for. Intuitively, the two adblockers are providing funding for a shared resource, and both would like to free ride as much as possible. We can also note that the content provider have no leverage against the adblockers. This is because the content provider would prefer to make deals with both adblockers rather than choosing one (muti-homing). As such, both adblocker acts as a monopolist towards the content provider.

Solving the above, in equilibrium, adblockers ask for $\mu_i = \frac{2}{3}$

3.5 Welfare Analysis

Proposition 4: As intensity of competition between adblockers, τ^{-1}, increase, consumer surplus is non-monotone - it is increasing when competition is low and decreasing when competition is high. Producer surplus, defined as the sum profit of the content provider and adblockers, is strictly reducing.

Since the number of ads whitelisted is a function of the intensity of competition between adblockers, a change in the intensity of competition directly affect the number of ads whitelisted. However, more advertising does not always improve total surplus as we have seen in our model of advertising funded content production. Therefore, an increase in competition may or may not increase total surplus. The level of competition between adblockers which maximises total surplus is given by

$$\tau^s = \begin{cases} \dfrac{b}{2c - r(1+\mu)} & \text{if } r < \dfrac{c}{1+\mu} \\ \dfrac{b}{c} & \text{if } r > \dfrac{c}{1+\mu} \end{cases}$$

The total surplus maximising τ^s sets a level of ads which takes into account of the nuisance cost on consumers and the surplus gained from allowing more content production to occur. Because an increase in revenue share to the adblocker reduces the amount of content production, as more revenue directed at the adblocker, the marginal benefit of more advertising is reducing, and hence the marginal benefit of more competition between adblockers higher relative to the marginal costs.

The level of ads whitelisted is only a part of the process of whitelisting. The other, of cause, is the revenue sharing deal.

Remark 1: An increase in revenue share μ to the adblocker strictly reduce total surplus.

Suppose that a social planner controls the revenue share scheme, and he chooses the same level of revenue share to both adblockers. All player are making decisions as outlined before. Then the social planner would prefer to give the adblockers no revenue share. We get this result since adblockers decisions do not depend on the size of the revenue share, but the amount of content produced by the publisher does. Furthermore, a reduction in the revenue share of one adblocker causes the other adblocker to reduce his. If we relax the assumption that adblockers will whitelist ads when indifferent, giving the adblocker an arbitrarily small share $\mu = \epsilon$ ensures that the adblocker strictly prefer to unblock ads.

So, it is clear that having whitelisting is better then having all ads blocked, but in many cases the whitelisting process produces outcomes where total surplus can be improved through changes in competition between adblockers of restrictions of revenue share an adblocker can charge a content provider. The question remains that if it's possible for adblocking can produce a better state of affairs, measured in total surplus, compared to the case with no adblocking, and the circumstances of which this can be achieved.

Proposition 4 states that adblocking strictly reduce producer surplus, and that consumer surplus is strictly higher with adblocking, but is reducing with the number of ads blocked when a large number of ads are already blocked. While consumers directly benefit when ads are blocked as they pay less nusiance cost per unit of content, they can also be harmed when too many ads are blocked leading to low levels of content production. We can summarize that the condition required for adblocking to be welfare enhancing through this inequality.

$$\frac{1}{2}r[b^2 - (1-\mu^2)\tau^2] < (1-\mu)\tau(b - c\tau)$$

On the left hand side with have the reduction in firm's profits with adblocking, and on the right hand side with have the increase in consumer surplus with adblocking. Because the gains from adblocking are captured by consumers, the level of competition which maximises consumer surplus must be lower than the level of competition which maximises total surplus.

Chapter 4
The Device Seller

Here I present a short extension to endogenous the intensity of competition between adblockers. It has become apparent that it is part of Apple's strategy to promote adblocking. For example, with the release of iOS9, Apple made it technically easier to make an adblocking software and allowing adblocking software to be distributed through the Apple Store. Using these methods, Apple promotes adblocking and increase competition between adblockers. In the chapter, I look at what may have motivated Apple and how Apple's actions will affect the welfare of consumers and content providers in equilibrium.

4.1 Choosing Competition

Suppose a monopolist device seller sells a device which enhances the consumer's utility based on the net utility a consumer gets from accessing content. To model this, I let the consumer's utility function be discounted by α unless the consumer buys a device from the device seller. The device seller is able to perfectly price discriminate. She makes an offer to consumer j to buy the device at price d_j. She can also make it easy for developers to produce adblockers, which is represented in the model as an increasing competition between 2 adblockers.

Additionally, I further restrict that the level of competition between adblockers to a maximum of $\tau < \frac{2b}{2c+1}$ to ensure that all consumers gets positive marginal utility from consuming content while using an adblocker.

The timing of the game is as follows.

1. The device seller makes an offer consumer j to buy the device at price d_j. Consumers accepts or rejects. The device seller chooses the intensity of competition between adblokcers, τ^{-1}.

2. Each adblocker proposes to the content provider a revenue share scheme. The content provider can accept or reject.

3. Content provider chooses q, the amount of content to produce. Simultaneously, adblockers i chooses a_i, the amount of ads users of the adblocker sees.

4. Consumers chooses which adblocker to use.

The utility function of the consumer is therefore

$$U_j = \begin{cases} \alpha q \left(b - c a_i - \tau |l_i - j| + \frac{1}{2}\tau \hat{j} \right) & \text{if consumer j does not buy the device} \\ q \left(b - c a_i - \tau |l_i - j| + \frac{1}{2}\tau \hat{j} \right) - d_j & \text{if consumer j buys the device} \end{cases}$$

And the profit function of the device seller, as long as every offer it made is accepted, is

$$\pi^h = \sum_{j=0}^{j=1} d_j$$

4.2 Equilibrium

In equilibrium, the device seller will set the price d_j such that consumers are indifferent between buying a device or not. We can therefore write the device sellers' profit function as

$$\pi_d = (1-\alpha) q \left(b - c a_i - \tau |l_i - j| + \frac{1}{2}\tau \hat{j} \right)$$

Aside from choosing the level of competition between adblockers, the presence of the device seller have no other impacts on the strategies of the adblockers, content providers and consumers. Their equilibrium strategies is derived in the same manner as in my model of adblocking, and we arrive at the same results. So given their strategies, the device seller would choose the level of competition between adblockers. Because the device seller profit is proportional to the consumer's surplus, it also happens that the level of competition the device seller would choose is also the level of competition which would maximise consumer surplus.

$$\tau^* = \frac{b}{2c}$$

Proposition 5: The level of competition the device seller chooses, τ^{-1*}, is strictly less then the level of competition which would maximise total surplus.

Compared to my model of adblocking, in this case the device seller captures a fixed portion of the consumer surplus. Therefore, the total surplus function is identical. Because the interior solution of total surplus maximising level of competition is driven by a strictly reducing producer surplus and a non-monotone consumer surplus, the device seller who acts to consumer surplus does so at great expense of content providers. Moreover, the revenue share going to the adblocker is unimportant to the device seller's choice of τ.

Appendix A

Proof of Proposition 1

First, we look at the first best level of advertising. The Total Surplus Function is

$$S = arq_c - \frac{1}{2}q_p^2 + q_c(b - ca)$$

The first derivative with respect to a is

$$\frac{\partial S}{\partial a} = q_c r - q_p b$$

When $q_p > q_c$, an increase in q_c strictly increase total surplus. Also, $q_c \leq q_p$. Therefore, to maximise total surplus, $q = q_p = q_c$.

$$\frac{\partial S}{\partial a} > 0 \text{ when } r > c$$
$$\frac{\partial S}{\partial a} < 0 \text{ when } r < c$$

Since $0 \leq a \leq A$, we have

$$a^{fb} = \begin{cases} A & \text{if } r > c \\ 0 & \text{if } r < c \end{cases}$$

Now, we look at the first best level of content production. Total surplus is given by

$$S = arq - \frac{1}{2}q^2 + q(b - ca)$$

The first and second derivative with respect to q is

$$\frac{\partial S}{\partial q} = ar - q + b - ca$$
$$\frac{\partial^2 S}{\partial q^2} = -1 < 0$$

Therefore, we have a maximum point. The FOC is

$$q^{fb} = ar + b - ca$$

Proof of Proposition 2

First, I'll derive equilibrium outcomes. To find equilibrium choice of content consumption, the utility of a consumer is

$$U = q_c(b - ca)$$

The first derivative with respect to q_c is

$$\frac{\partial U}{\partial q_c} = b - ca$$

Therefore

$$\frac{\partial U}{\partial q_c} > 0 \text{ when } b > ca$$
$$\frac{\partial U}{\partial q_c} < 0 \text{ when } b < ca$$

Since $q \leq q_c \leq q_p$, we have

$$q_c = \begin{cases} q_p & \text{if } b \geq ca \\ 0 & \text{if } b < ca \end{cases}$$

Given the consumer's choice of content consumption, the content provider chooses the level of advertising the profit function of the content provider is

$$\pi_p = \begin{cases} arq_p - \frac{1}{2}q_p^2 & \text{if } b \geq ca \\ 0 & \text{if } b < ca \end{cases}$$

Suppose the content provider choose a level of a such that $b \geq ca$. Then

$$\frac{\partial \pi_p}{\partial a} = rq_p > 0$$

Therefore, if the content provider choose a such that $b \geq ca$, he would choose $a = \frac{b}{c}$. As the alternative is $\pi_p = 0$, he would choose $a^* = \frac{b}{c}$ when $\pi_p > 0$. the condition for this is

$$\frac{b}{c}rq_p - \frac{1}{2}q_p^2 > 0$$
$$\frac{b}{c}r > \frac{1}{2}q_p$$

Also given the consumer's choice of content consumption, the content provider choose the level of content production

$$\pi_p = arq - \frac{1}{2}q^2$$

The first and second derivative is

$$\frac{\partial \pi_p}{\partial q} = ar - q$$
$$\frac{\partial^2 \pi_p}{\partial q^2} = -1 < 0$$

The FOC is

$$q^* = ar$$

Suppose $a^* = \frac{b}{c}$

$$q^* = \frac{b}{c}r$$

Check that $\frac{b}{c}r > \frac{1}{2}q_p$

$$\frac{b}{c}r > \frac{1}{2}ar$$
$$\frac{b}{c} > \frac{b}{2c}$$

When is true. Therefore the condition for $a^* = \frac{b}{c}$ is met.

Now let's consider the level of advertising which maximises total surplus given that advertising funds content production and we must respect the consumer's participation constraint. The total surplus function is:

$$S = arq_c - \frac{1}{2}q_p^2 + q(b - ca)$$

In equilibrium, $q = q_c = q_p = ar$ and $a \leq \frac{b}{c}$

$$S = \frac{1}{2}a^2r^2 + ar(b - ca)$$

The first and second derivative is

$$\frac{\partial S}{\partial a} = ar^2 + rb - 2cr$$
$$\frac{\partial^2 S}{\partial a^2} = r^2 - cr$$

For the second derivative to be positive, we need $r < c$. Then we have the FOC

$$ar^2 + rb - 2cr = 0$$

When $r \geq c$, the turning point is a minimum so we have a boundary solution. we know that $0 \leq a \leq \frac{b}{c}$. When $a = 0$, $S = 0$. When $a = \frac{b}{c}$, $S = \frac{1}{2}\left[\frac{b}{c}r\right]^2 > 0$. Together, we arrive at the level of ads the social planner would choose, which is

$$a_s = \begin{cases} \dfrac{b}{2c - r} & \text{if } r < c \\ \dfrac{b}{c} & \text{if } r \geq c \end{cases}$$

Proof of Proposition 3

The marginal consumer is indifferent between the 2 adblockers.

$$\beta q(b - a_1 - \tau\hat{j}) = \beta q[b - a_2 - \tau(1 - \hat{j})]$$
$$\hat{j} = \frac{1}{2} + \frac{1}{2\tau}(a_2 - a_1)$$

The number of consumers using adblocker 1 and 2 is given by

$$z_1 = \hat{j} = \frac{1}{2} + \frac{1}{2\tau}(a_2 - a_1)$$
$$z_2 = 1 - \hat{j}$$
$$= \frac{1}{2} + \frac{1}{2\tau}(a_1 - a_2)$$
$$z_i = \frac{1}{2} + \frac{1}{2\tau}(a_{-i} - a_i)$$

Now let's consider the adblocker's chocie of the number of ads to whitelist given consumer's choice. By substituting the marginal consumer into the profit function of an adblocker, we can find the reaction function.

$$\pi_i = qr\mu_i a_i \left[\frac{1}{2} + \frac{1}{2\tau}(a_{-i} - a_i)\right]$$

The first derivative is

$$\frac{\partial \pi_i}{\partial a_i} = qr\mu_i \left(\frac{1}{2} + \frac{1}{2\tau}(a_{-i} - a_i) - \frac{1}{2\tau}a_i\right)$$

The second derivative is

$$\frac{\partial^2 \pi_i}{\partial a_i} = -\frac{qr\mu_i}{\tau}$$

Since the second derivative is negative, the first order condition is a maxima.

$$\begin{aligned} &\frac{1}{2} + \frac{1}{2\tau}(a_{-i} - a_i) - \frac{1}{2\tau}a_i = 0 \quad \text{(FOC)} \\ &a_i = \frac{\tau}{2} + \frac{1}{2}a_{-i} \end{aligned}$$

Since both adblockers solves a symetric problem, $a_i = a_{-i}$

$$a_i = \tau$$

The content provider's must choose the amount of content to produce at the same time as adblockers choose how many ads to whitelist. His profit function is

$$\begin{aligned} \pi_p &= qr(1-\mu_1)a_1z_1 + qr(1-\mu_2)a_2z_2 - \frac{1}{2}q^2 \\ &= qr(1-\mu_1)a_1\left[\frac{1}{2} + \frac{1}{2\tau}(a_2 - a_1)\right] + qr(1-\mu_2)a_2\left[\frac{1}{2} + \frac{1}{2\tau}(a_1 - a_2)\right] - \frac{1}{2}q^2 \end{aligned}$$

The first derivative is

$$\frac{\partial \pi_p}{\partial q} = r(1-\mu_1)a_1\left[\frac{1}{2} + \frac{1}{2\tau}(a_2 - a_1)\right] + r(1-\mu_2)a_2\left[\frac{1}{2} + \frac{1}{2\tau}(a_1 - a_2)\right] - q$$

The second derivative is

$$\frac{\partial^2 \pi_p}{\partial q^2} = -1$$

Since the second derivative is negative, the first order condition is a maxima.

$$r(1-\mu_1)a_1\left[\frac{1}{2}+\frac{1}{2\tau}(a_2-a_1)\right]+r(1-\mu_2)a_2\left[\frac{1}{2}+\frac{1}{2\tau}(a_1-a_2)\right]-q=0 \quad \text{(FOC)}$$

Since $a^* = \tau$

$$q = r(1-\mu_1)\frac{\tau}{2} + r(1-\mu_2)\frac{\tau}{2}$$

Now lets look at the revenue sharing scheme the adblocker will propose given the expected reactions of all the players. Substituting equilibrium q, a, and z, the adblocker chooses to a revenue share scheme to propose.

$$\pi_i = \frac{\tau^2}{4}(2-\mu_i-\mu_{-i})\mu_i r^2$$

The first derivative is

$$\frac{\partial \pi_i}{\partial \mu_i} = \frac{\tau^2}{4}(2-2\mu_i-\mu_{-i})r^2$$

The second derivative is

$$\frac{\partial^2 \pi_i}{\partial \mu_i} = -\frac{\tau^2 r^2}{2}$$

Since the second derivative is negative, the first order condition is a maxima. The reaction function is

$$\frac{\tau^2}{4}(2-2\mu_i-\mu_{-i})r^2=0 \quad \text{FOC}$$
$$\mu_i = 1-\frac{1}{2}\mu_{-i}$$
$$\mu_i=\frac{2}{3}$$

Proof of Proposition 4

Total Surplus is given by

$$S = qra_1z_1 + qra_2z_2 - \frac{1}{2}q^2 + q(b-ca_i)$$

We have the social planer in charge of setting our whitelist, while other players react to the choice of whitelist. Suppose $a_1 = a_2 = a$. In equilibrium, $q^* = r(1-\mu)a$, $z_1 = z_2 = \frac{1}{2}$.

$$S = (1-\mu)r^2a^2 - \frac{1}{2}(1-\mu)^2r^2a^2 + r(1-\mu)a(b-ca)$$

The first and second derivative with respect to a is

$$\begin{aligned}
\frac{\partial S}{\partial a} &= 2(1-\mu)r^2a - (1-\mu)^2r^2a + r(1-\mu)b - 2r(1-\mu)ca \\
&= (1-\mu)ra[r(1+\mu)-2c] + r(1-\mu)b \\
\frac{\partial^2 S}{\partial a^2} &= (1-\mu)r[r(1+\mu)-2c] \\
&= (1-\mu^2)r^2 - 2(1-\mu)rc
\end{aligned}$$

The second derivative is negative when

$$r < \frac{2c}{1+\mu}$$

The first order condition is

$$a^s = \frac{b}{2c - r(1+\mu)}$$

We have restricted

$$a \leq \frac{b}{c}$$

The first order condition exceeds this level of a when

$$r < \frac{c}{1+\mu}$$

Note that when this holds, the second derivative is strictly negative.

Now let's decompose the total surplus function into it's parts. Producer surplus and consumer surplus Without adblocking, consumer have a utility of 0 and firm's profit is given by

$$\pi_p = \frac{1}{2} r^2 b^2$$

With adblocking, the joint profit of content providers and adblockers is

$$\pi_p + \pi_1 + \pi_2 = \frac{1}{2}(1-\mu^2) r^2 \tau^2$$

and consumer's utility is

$$U = r(1-\mu)(b - c\tau)\tau$$

Therefore, if the increase in consumer's utility is greater than the decrease in firm's profits, then

$$\frac{1}{2} r[b^2 - (1-\mu^2)\tau^2] < (1-\mu)\tau(b - c\tau)$$

Remark 1

Total Surplus is given by

$$S = qra_1 z_1 + qra_2 z_2 - \frac{1}{2} q^2 + q(b - ca_i)$$

Suppose $\mu_1 = \mu_2 = \mu$. In equilibrium, $a^* = \tau$, $q^* = r(1-\mu)\tau$, $z_1 = z_2 = \frac{1}{2}$.

$$S = \frac{1}{2}(1-\mu)^2 r^2 \tau^2 + r(1-\mu)\tau(b - c\tau)$$

The above function is strictly reducing with μ.

Proof of Proposition 5

The profit function of the device seller is

$$\pi_d = (1-\alpha)q\,(b - ca_i)$$

In equilibrium, $q^* = r(1-\mu_1)\frac{\tau}{2} + r(1-\mu_2)\frac{\tau}{2}$, $a_i = \tau$, $\mu_1 = \mu_2 = \mu = \frac{2}{3}$.

$$\pi_d = (1-\alpha)r(1-\mu)\tau(b-c\tau)$$
$$\frac{\partial \pi_d}{\partial \tau} = (1-\alpha)r(1-\mu)(b-2c\tau)$$
$$\frac{\partial^2 \pi_d}{\partial \tau^2} = -(1-\alpha)r(1-\mu)2c < 0$$

The equilibrium level of τ chosen is therefore

$$\tau^* = \frac{b}{2c}$$

Since

$$\tau^s = \begin{cases} \dfrac{b}{2c - r(1+\mu)} & \text{if } r < \dfrac{c}{1+\mu} \\ \dfrac{b}{c} & \text{if } r > \dfrac{c}{1+\mu} \end{cases}$$

We can see that in both cases

$$\tau^* < \tau^s$$

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