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Yuxin Chen
New York University

K. Sudhir
Yale School of Management

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Yuxin Chen
Stern School of Business
New York University
44 W Fourth St, MEC 8-95
New York, NY 10012-1126
Email: ychen@stern.nyu.edu
Phone: 212-998-0511
Fax: 212-995-4006

K. Sudhir
Yale School of Management
135 Prospect St, PO Box 208200
New Haven, CT 06520-8200
Email: sk389@mail.som.yale.edu
Phone: 203-432-3289
Fax: 203-432-3003

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Implications for Price Competition on the Internet

Abstract

The Internet has dramatically reduced search costs for customers through tools such as shopbots. The conventional wisdom is that this reduction in search costs will increase price competition leading to a decline in prices and profits for online firms. In this paper, we provide an argument for why in contrast to conventional wisdom, *competition may be reduced and prices may rise as consumer search costs for prices fall*. Our argument has particular appeal in the context of the Internet, where email targeting and the ability to track and record customer behavior are institutional features that facilitate cost effective targeted pricing by firms. We show that such targeted pricing can serve as an effective counterweight to keep average prices high despite the downward pressure on prices due to low search costs. Surprisingly, we find that the effectiveness of targeting itself improves as search costs fall; therefore prices and profits can increase as search costs fall.

The intuition for our argument is as follows: Consider a market where consumers are heterogeneous in their loyalty as well as their cost per unit time to search. In the brick and mortar world, it takes consumers a very large amount of time to search across multiple firms. Therefore few customers will search in equilibrium because the gains from search will be relatively small compared to the cost of search. In such a market, a firm will not be able to distinguish whether its customers bought from it due to their high loyalty or due to their unwillingness to search for low prices because of the high search cost.

On the Internet, the amount of time to search across multiple stores is minimal (say zero). Now irrespective of their opportunity cost of time, all consumers can search because the time to search is negligible. If in spite of this, a consumer does not search in this environment, she is revealing that her loyalty to the firm that she buys from is very high. The key insight is that as search becomes easy for everyone, then *lack of search* indicates strong customer loyalty and thus can be used as a proxy to segment the market into loyal and price sensitive segments.

Thanks to email technology, firms can selectively set differential prices to different customers, i.e. a high price to the loyal segment and a low price to the price sensitive segment, at relatively low cost. The increased competition due to price transparency caused by low search costs can thus be offset by the ability of firms to price discriminate between their loyal (price insensitive) customers and their price sensitive customers. In fact, we find that it can reduce the extent of competition among the firms and raise their profits. Most surprisingly, the positive effect of targeting on prices improves when search costs fall, because firms can learn more about the differences in

customer loyalty, thus improving the effectiveness of targeted pricing. The effectiveness of targeted pricing however is moderated by the extent of opt-in by customers who give their permission for firms to contact them directly by email.

Our analysis offers interesting strategic insights for managers about how to address the competitive problems associated with low search costs on the Internet:

(1) It suggests that firms should invest in better technologies for personalization and targeted pricing so as to prevent the Internet from becoming a competitive minefield that destroys firm profitability. In fact we show that low search costs can facilitate better price personalization and can thus aid in improving the effectiveness of targeted pricing efforts.

(2) The analysis also offers guidelines for online customer acquisition efforts. The critical issue for competitive advantage is not in increasing market share per se, but in increasing the loyalty of customers. While a larger share of very loyal customers reduces competitive intensity, surprisingly a larger share of customers who are not very loyal can be a competitive disadvantage. In order for customer acquisition to be profitable, it should be accompanied by a superior product or service that can ensure high loyalty.

(3) Investing in online privacy initiatives that assures consumers that their private information will not be abused other than to offer them “deals” is worthwhile. Such assurances will encourage consumers to opt into firm mailing lists. This facilitates successful targeting which in turn ameliorates the competitive threats due to low search costs on the Internet.

(4) When the overwhelming majority of customers are satisfied with online privacy, the remaining privacy conscious customers who are not willing to pay a higher price to maintain their privacy will be left out of the market. While this may be of some concern to privacy advocates, it is interesting that total consumer welfare can be higher even if some consumers are left out of the market.

Our analysis captures the competitive implications of the interaction between two institutions facilitated by the Internet: Shopbots and Emails. But the research question addressed is more fundamental: What is the nature of competition in an environment with *low costs for both consumer search* and *firm-to-consumer personalized communications?* The strategic insights obtained in the paper may be beneficially applied even to offline businesses that can replicate such an environment. For example, offline firms could have websites on which they post prices allowing for easy price comparisons. They could also use tools such as frequency programs to create addressable databases that enable them to communicate with customers by direct mail and email (as many airlines and stores do).

1. Introduction

There is a standard argument in the theoretical literature on price search that as consumer search costs fall, competition will intensify in response to the greater transparency in prices. This argument implies that on the Internet, which is characterized by extremely low search costs (where customers can find out prices across a large number of online stores through technologies such as shopbots), price competition will be very intense and profitability will be low. Theoretical papers such as Bakos (1997), Zettelmeyer (1998) and conceptual discussions as in Alba et al (1997), Shapiro and Varian (1999) have come to a similar conclusion. Such arguments have also had tremendous impact among business professionals and the popular press.

For example, in his 1995 bestseller 'The Road Ahead', Bill Gates suggests that the Internet "will carry us into a new world of low-friction, low-overhead capitalism, in which market information will be plentiful and transaction costs low. It will be a shopper's heaven." A Business Week article tellingly titled, " A Market Too Perfect for Profits", (Kuttner, 05/11/98) says "The Internet is a nearly perfect market because information is instantaneous and buyers can compare the offerings of sellers worldwide. The result is fierce price competition, dwindling product differentiation, and vanishing brand loyalty."

The logical question that follows from this line of argument however is the question asked in a Los Angeles Times article, "If the Internet offers the "lowest prices on Earth" just a mouse click away, … then who can make any money?" (Gaw, 12/14/98) Yes, if all that the Internet serves is to intensify price competition, why would any firm invest on the Internet? We do see some well-publicized failures of some big name e-tailers such as EToys and Pets.com. But is such fate inevitable for the surviving e-tailers too?

In this paper, we provide an argument for why in contrast to conventional wisdom, *competition may be reduced and prices may rise as consumer search costs for prices fall*. Our argument has particular appeal in the context of the Internet, where shopbots, email targeting and the ability to record and track customer behavior are institutional features that facilitate the applicability of our argument. We show that our argument may help to resolve the apparently divergent findings in empirical research on the average levels of prices on the Internet.

The basic intuition for our argument is as follows: Consider a market where consumers are heterogeneous in their loyalty/preference as well as their costs per unit time to search.

Suppose in one environment (as in the brick and mortar world), it takes consumers a very large amount of time to compare prices across multiple firms. In such an environment, very few customers will search prices of different firms because the gains from search will be relatively small compared to the cost of doing it. A firm in such a market will not be able to distinguish customers who bought from it due to their high loyalty from those who bought from it due to their unwillingness to search for low prices because of the high search costs.

Now suppose in another environment (as in the online world), the amount of time to search across multiple firms is minimal (say zero). Now irrespective of their opportunity cost of time, all consumers can search because the time to search is negligible. If in spite of this a consumer does not search in this environment, she is revealing that her loyalty to the firm that she buys from is very high. This enables the firm to segment the market in terms of customer loyalty. If firms can then set differential prices, i.e. a high price to the loyal (price insensitive) segment and a low price to the price sensitive segment, the increased competition due to price transparency caused by low search costs can be offset by the increased ability for firms to price discriminate. In fact, under certain circumstances, the competition among firms can be reduced to the extent that their profits can actually rise with a decline in consumer search costs for price information.

The central idea of the above argument is that as search becomes easy for everyone, then *lack of search* indicates consumer loyalty and thus can be used as a proxy to segment the market. However, if search is hard, then lack of search can either indicate that consumers have high value for time or that they are highly loyal to firms. Consequently, firms are unable to segment the market in such an environment leading to greater competition and lower profits.

Critical to the applicability of our argument is that firms should be able to track the individual customer's behavior over time so that they can classify the customer into a loyal or price sensitive customer. On the Internet, it is relatively easy to record a customer's shopping behavior and categorize the customer into segments. Furthermore, in order to profit from the segmentation information revealed by consumer price search, firms should be able to selectively offer lower prices to the price sensitive consumers relative to the loyal consumers. On the Internet, such a price discrimination strategy can be implemented by selectively delivering email coupons to price sensitive customers (because firms have access to email addresses of consumers), while the loyal customers pay the higher prices posted on firms' websites. For example, companies such as Amazon, Barnes and Noble and Wine.com routinely use purchase histories of customers to pepper them with offers (Stellin, 08/21/2000). Email targeting is effective because emails can be delivered instantaneously and the responses are also relatively fast comparing to the promotional offerings in the offline world. According to the New York Times, “Email is a relatively inexpensive marketing tool, ranging from a penny to a quarter for each message, compared to $1-$2 for each piece of direct mail campaigns in the actual world. Moreover, email campaigns produce immediate results, no small factor in an industry, where speed is critical.” (Stellin, 08/21/2000). Email marketing has been progressively increasing with Forrester Research and eMarketer forecasting its growth in excess of 100% annually.[1] With email targeting, firms are able to effectively utilize information about consumer loyalty (gleaned by observing consumer purchase activities) to segment the market and set targeted prices. As search costs drop and more consumers search online, firms can learn more about its customers. This can improve the effectiveness of targeted pricing and can help raise firms’ prices and profits. Surprisingly, it is even possible for firms’ prices and profits to be higher when consumer search cost is zero than when it is infinite.

As firms’ ability to gather consumer information and send targeting emails increases on the Internet, so does consumers’ concern for their privacy. Both consumers and firms are now increasingly taking online privacy seriously. Typically, customers can choose to “opt-out” (where customers by default receive emails, but can choose not to participate) or “opt-in” (where customers will not be included by default in mailings, but will need to explicitly sign in) for mailings from firms (Petersen, 02/12/2001). Such policies are a means of obtaining permission from customers to send them email offers and are also referred to as “permission marketing” (Godin and Peppers, 1999). Permission marketing of course limits the ability of firms to operationalize the segmentation of the market. From our modeling viewpoint, we do not distinguish between opt-in and opt-out policies and will use the term "opt-in". Our model indicates that “opt-in” is a critical variable. It reflects the permission or trust a firm gets from the consumers to communicate with them directly. At low levels of “opt-in”, only posted prices are effective and competition online is similar to the offline market where lower search costs

[1] The Forrester forecast is discussed in Stellin (08/21/2000) and the eMarketer forecast is provided in the eMail Marketing Report by the firm eMarketer.

intensify competition. As “opt-in” increases, firms can price discriminate their consumers more effectively and their profitability increases as consumer search costs fall. In fact, beyond a critical level of “opt-in,” the posted price will become so high that only the loyal segments in the market will buy the product at the posted prices and the price-sensitive but privacy conscious customers who opt out will find it not worthwhile to buy the product at posted prices. Thus as opt-in increases to a critical level with consumers gaining confidence in the technologies that help guard privacy, the remaining privacy conscious customers who do not opt-in will be left out of the market.

In recent empirical research there appears to be some divergence in the findings of average levels of posted prices at Internet stores. While Bailey (1998) found that average levels of prices for books and CDs were higher online than offline between 1996-1997, Brynjolfsson and Smith (2000) found that the average levels of prices for books and CDs were lower online than offline in 1999. Clay et al. (2001) however find that the average prices for books have been increasing online between mid 1999 to January 2000. If all of these results were indeed consistent, then online posted prices should have followed a U-shaped pattern with prices falling between 1997 and 1999 and then rising towards 2000. If we recognize that the costs of consumer search have continued to fall and email targeting activities have continued to increase over this period, the predictions from our model would be consistent with such a U-shaped pattern on posted prices.

The findings in this paper should be contrasted with two closely related streams of research in the literature: In the first stream of literature linked to search costs, Bakos (1997) showed in an influential paper that the low search costs make electronic marketplaces vulnerable to intense competition. Zettelmeyer (1998) argued that firms can strategically manipulate the level of search costs and thus the intensity of competition by making it harder for consumers to judge the quality of products. Lal and Sarvary (1999) classify goods as those with primarily digital attributes and non-digital attributes[2] and show that the Internet can reduce the intensity of competition for goods with non-digital attributes when search costs fall. Unlike Zettelmeyer (1998) and Lal and Sarvary (1999), we do not appeal to quality uncertainty arguments when

[2] A digital attribute is one that can be communicated easily over the web. Non-digital attributes are things such as texture of clothes etc. which cannot be communicated over the web.

showing that low search costs can decrease competitive intensity. Our results are particularly applicable to product categories such as books and CDs, for which quality uncertainty and non-digital attributes are not critical.

This paper is also closely tied to the literature on targeting. Thisse and Vives (1988) and Shaffer and Zhang (1995) show that competition will become more intense as firms can target consumers. They assume that firms have perfect information on the consumers being targeted. However, Chen et al (2001) show that market competition can be softened by firms' targeting activities when their information on consumers is not precise. In contrast to Chen et al. (2001), we are able to show that competitive intensity can be reduced in a low search cost environment even if firms can target consumers with perfect information.

The rest of the paper is organized as follows: In §2, we introduce the basic model and in §3, we analyze the basic model and discuss the main results of the paper. In §4, we discuss several extensions and also relax some of the technical assumptions of the basic model to check the robustness of the results. §5 concludes.

2. Model

Consider two competing firms in a product category selling through the Internet. The marginal production cost of each firm is assumed to be zero without loss of any generality. Each firm i has two loyal segments of customers: a "strong loyal segment", s_i, and a "weak loyal segment", w_i. Consumers in the strong loyal segment, s_i, have a reservation price r_s for firm i's product and they will never switch to buy from firm j ($j=3-i$). However, consumers in the weak loyal segment, w_i, have a reservation price r_w for firm i's product and a reservation price r_w-L for firm j's product. Therefore, firm i's weak loyal consumers will switch to buy from firm j if the price difference between two firms is larger than L, i.e. if p_i-p_j>L, and $p_j \le r_w$. We assume that $r_w<r_s$, implying that consumers in the strong loyal segment have higher willingness to pay than those in the weak loyal segment. The strong loyal segments in our model are similar to the loyal segments in the model used by Narasimhan (1988) and the weak loyal segments in our model are similar to the consumer segments in the model used by Raju, Srinivasan and Lal (1990). Each consumer makes a purchase decision to maximize her consumer surplus and buys at most one unit from the product category. If a consumer is indifferent between buying from a firm and making no purchase at all, we assume that she will make the purchase. Without loss of any

generality to our results, we further assume $r_w = 1$, $r_s = r$, and the size of each of the four segments (two weak loyal and two strong loyal segments) to be equal to 1.

When consumers use shopbots (e.g. Mysimon.com), they can find prices across a large number of online stores at one shot with a few mouse clicks. We assume that consumers use shopbots to search online and the cost of using shopbots to compare prices of the two firms is c_i for consumer *i*. c_i is distributed uniformly between *0* and *C* in all consumer segments. The heterogeneity in consumer search costs can result from the difference in consumers' technical savvy with the Internet and shopbots, the speed of their Internet connection and their value of time.

Given the consumer segmentation described earlier, it is obvious that consumers in the strong loyal segments have no incentive to search for the price information of the competing firms in the market. Price comparison provided by a shopbot has no value to those consumers because their shopping decisions will not be affected by the price comparison. However, consumers in the weak loyal segment have incentives to search for price information, because it is optimal for them to switch from the firm they are weakly loyal to if the price at the other firm is low enough. This feature of our model captures a simple but important aspect of consumer price search behavior: The search behavior of a consumer is determined not only by her search cost but also by her expected gains from search. Due to the heterogeneity in consumers' à priori preferences (loyalty) for the two firms, even consumers with the same search cost may have different observed search behavior. Empirically, Johnson et al. (2001) find that consumer search activities for books, CDs and travel sites are quite heterogeneous even though shopbots can be used to compare prices at low search costs.

Denote β to be the proportion of consumers in either firm's weak loyal segment who use shopbots to search firms' prices. These "price searchers" may switch firms if the price difference between two firms is larger than L. The remaining consumers who do not search, shop at the firm they are loyal to. We should expect that the proportion of consumers that search prices will increase when consumer search cost c_i decreases and/or the expected gain from price comparison, *g*, increases. Therefore, $\beta=\beta(C,g)$ with $\frac{\partial \beta}{\partial C} \leq 0$ and $\frac{\partial \beta}{\partial g} \geq 0$. In the basic model here, we treat β as exogenous. In §4, we will extend the basic model to formally model consumer price search behavior as endogenously determined by search cost and the expected gain from price comparison. Our main conclusions from the basic model are robust to such an extension.

While the Internet enables consumers to compare prices across multiple competing firms at one shot through shopbots, it also enables firms to contact consumers directly with targeted email offerings such as electronic coupons. Importantly, a firm's targeting ability is highly related to the consumer's level of search. As consumers search more, firms can also target more consumers with more precisely targeted prices. Consider the following example: Without consumer search, a consumer in Firm 2's weak loyal segment, w_2, will never search and always buy from Firm 2. Consequently, Firm 1 will have no information about consumers in w_2 unless it buys such information from external data vendors. However, if β proportion of w_2 consumers searches both firms' prices, they may visit and purchase from Firm 1. Consequently, Firm 1 will be able to record information about them and potentially target them with emailed coupons. Furthermore, because the Internet enables firms to observe competitors' prices easily (with technology similar to shopbots, that have been dubbed "pricebots"[3]), firms will be able to identify the type of consumers in their database if there are price variations in the market and consumers stay in the market for a sufficiently long time. For instance, from Firm 1's perspective, consumers who purchased at $1<p_1\leq r$ must be its strong loyal customers; consumers who never purchased at $p_1>1$ but purchased at $p_1\leq 1$ and $p_1-p_2>L$ must be its weak loyal customers who do not search; consumers who only purchased at $p_1 \leq 1$ and $p_1-p_2 < -L$ must be its competitor's weak loyal customers who search, and the remaining consumers must be its weak loyal customers who search.

To operationalize the above discussion on the interaction between consumer price search behavior and firms' email targeting ability, we assume that each firm has a database with individual level information on consumers in 1) its strong loyal segment, s_i, 2) the proportion of its weak loyal segment that do not search, $w_{i(1-\beta)}$, 3) the proportion of its weak loyal segment that search, $w_{i\beta}$, and 4) the proportion of its competitor's weak loyal segment that search, $w_{j\beta}$. Firms can identify each consumer in its database in terms of her membership in the segments of s_i,

[3] Buy.com boasts that it offers "the lowest prices on earth" by regularly monitoring the competitive prices and updating its prices, using such technology.

$w_{i(1-\beta)}$, $w_{i\beta}$, and $w_{j\beta}$, and can potentially target them with different prices through promotional offers such as electronic coupons.[4]

Because of the time constraints in reading emails and the growing concerns about online privacy, some consumers may not read or want to be targeted by emails. Typically firms give consumers the option to either "opt out" of an email list or "opt in" to an email list. We do not distinguish between opt-in and opt-out policies and will use the term "opt-in" hereafter. Actually, we will use the term "opt-in" in an even broader sense in the paper by treating consumers who receive targeting emails but do not open or read them as if they have not "opted in".

As long as the cost of checking an email is nonzero, a firm's strong loyal consumers and weak loyal consumers who do not search (i.e. consumers in s_i, and $w_{i(1-\beta)}$) have no incentive to opt in. A firm sending email to such a consumer will optimally set the targeting price equal to her reservation price because there is no competition from the other firm for the consumer. Therefore the consumer will have no gain from reading the email, but incur a non-zero cost to check it. As a result, the expected utility gain from reading a target email is negative for a consumer in segments s_i, and $w_{i(1-\beta)}$. Hence consumers who do not search will have no incentive to opt-in and therefore cannot be targeted by firms. This further illustrates the strong correlation between consumers' search behavior and firms' targeting ability.

However, consumers who search for prices have incentive to receive and read emails because firms have incentive to compete for them with prices lower than posted prices on their websites. We assume that θ proportion of consumers who search for prices are potentially responsive to firms' email targeting, i.e. they have opted in. The remaining consumers either ignore targeting emails or choose to not receive emails because of time constraint or privacy concerns. θ can also be interpreted as a measure of consumer acceptance to targeting emails or the effectiveness (responsiveness) of targeting emails.

The marginal cost of sending a targeting email is assumed to be zero, consistent with the relatively low cost of sending an email message relative to direct mail. Each firm simultaneously sets its posted price p_i to all consumers and email targeting prices p^x_{ie} ($x=w_{i\beta\theta}$ or $w_{j\beta\theta}$) to its own weak loyal consumers and its competitor's weak loyal consumers who search prices and opt in.

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[4] Our results will not be changed even if firms cannot distinguish consumers from s_i, and $w_{i(1-\beta)}$.

The basic model described in this section is parsimonious in nature but it captures the key economic effects resulting from the interaction between consumer search behavior and firms' targeting activities. There are only four parameters in the basic model: *r* reflects the degree of consumer heterogeneity; *L* reflects the intensity of competition in the market; β reflects the magnitude of consumer search; θ reflects the extent of consumer acceptance to email targeting; and consequently βθ reflects the magnitude of firms' targeting activities.

Before we proceed to the formal analysis of the model, we make three additional technical assumptions. First, we assume that $1<r<2$. This assumption guarantees that each firm will sell to both of its two consumer segments in the absence of consumer search. Second, we assume that $\frac{1}{6}<L<\frac{1}{3}$. This assumption makes it possible for weak loyal consumers to switch in equilibrium and ensures tractability for the model.[5] Finally, we assume that consumers incur no cost to go to the website of the firm they are loyal to.[6] Thus, a consumer may still visit the website of the firm she is loyal to and buy from there even if she expects to be charged at her reservation price. Discussions on the robustness of our conclusions with respect to the relaxations of these technical assumptions will be provided in §4 where we discuss extensions of the basic model.

3. Analysis

We start our analysis by examining firms' equilibrium decisions regarding email targeting. After receiving targeting emails from both firms, Firm 1's weak loyal consumers who search for prices and opt in (i.e. consumers in the $w_{1\beta\theta}$ segment) compare the two email offerings and buy at Firm 1 if and only if $p^{w1\beta\theta}{}_{1e} - p^{w1\beta\theta}{}_{2e} \leq L$ and $p^{w1\beta\theta}{}_{1e} \leq 1$. Therefore, competition for this segment results in Firm 1 charging L and Firm 2 charging 0 in equilibrium. Consequently,

[5] This assumption on L is similar to that made in Raju, Srinivasan and Lal (1990) (page 291).

[6] For a consumer in the strong loyal segments, her cost of going to the website she is not loyal to is irrelevant to our analysis. For a consumer in the weak loyal segment, her cost of going to the website she is not loyal to can be regarded as a part of L.

Firm 1 obtains a profit of βθL and Firm 2 obtains zero profit from this segment.[7] Similarly, in equilibrium Firm 1 charges 0 and Firm 2 charges L for Firm 2's weak loyal consumers who search and opt in (the $w_{2\beta\theta}$ segment). Firm 1 obtains zero profit and Firm 2 obtains a profit of βθL from this segment. Overall, each firm obtains a total profit of βθL from the consumers targeted by emails.

Now consider the market for firms' posted prices. Denoting π_{io} and π_i as firm i's profit associated with its posted price and its total profit respectively, we have $\pi_i = \pi_{io} + \beta\theta L$ where

$$\pi_{io} = 0 \qquad \text{if } p_i > r, \qquad (1)$$

$$\pi_{io} = p_i \qquad \text{if } 1 < p_i \leq r, \qquad (2)$$

$$\pi_{io} = p_i + p_i(1-\beta) \qquad \text{if } p_i > p_j + L \text{ and } p_i \leq 1, \qquad (3)$$

$$\pi_{io} = p_i + p_i(1-\beta) + p_i\beta(1-\theta) \qquad \text{if } p_j - L \leq p_i \leq p_j + L \text{ and } p_i \leq 1, \qquad (4)$$

$$\pi_{io} = p_i + p_i(1-\beta) + 2p_i\beta(1-\theta) \qquad \text{if } p_i < p_j - L \text{ and } p_i \leq 1. \qquad (5)$$

In the above equations, p_i is Firm *i*'s profit from its strong loyal segment when $p_i \leq r$ and $p_i(1-\beta)$ is Firm i's profit from its weak loyal consumers who do not search when $p_i \leq 1$.When $p_j - L \leq p_i \leq p_j + L$ and $p_i \leq 1$, Firm *i* gets its weak loyal consumers who neither search nor opt-in for email lists. Its profit from those consumers is $p_i\beta(1-\theta)$ as shown in (4). Finally, when $p_i < p_j - L$ and $p_i \leq 1$, Firm *i* gets both its own and the competitor's weak loyal consumers who do not search and do not opt in email lists. Its profit from them is $2p_i\beta(1-\theta)$ as shown in (5).

By the same logic as in Raju, Srinivasan and Lal (1990), firms' equilibrium posted prices may involve mixed strategies. Solving for firms' optimal decisions based on the profit functions given in equations (1)-(5), we can obtain firms' equilibrium posted prices (or expected posted prices, $E_i(p)$, in the case of mixed strategy equilibrium) and total profits as described in Lemma 1 below.

Lemma 1: *Firms' competition in posted prices results in equilibrium in one of the following five exhaustive and mutually exclusive parameter regions.*

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[7] If firms incur positive variable costs and/or fixed costs to send emails, both firms' equilibrium pricing decisions are in mixed strategies. Firm 2 has positive probability of not sending emails and it charges non-zero price. However, the resulting equilibrium profits are the same as in the case where emails are costless. Therefore, our analysis below is not affected.

Region I *(r<2-βθ and* $L \geq \frac{\beta(1-\theta)}{2+\beta-2\beta\theta}$*):*

$p^I_i=1$, $\pi^I_{io}=2-\beta\theta$, and $\pi^I_i=2-\beta\theta(1-L)$.

Region II *(r<2-βθ and* $\frac{r}{2-\beta\theta}-\frac{2-\beta\theta}{2+\beta-2\beta\theta} \leq L < \frac{\beta(1-\theta)}{2+\beta-2\beta\theta}$*):*

$$E_i(p)=\frac{p_n(2-\beta\theta)}{\beta(1-\theta)}[\ln\frac{1-L}{p_n(p_n-L)}+L(1-\frac{1}{p_n}+\frac{1}{p_n-L})+p_n(1-\frac{1}{p_n-L})+1]+p_n-\frac{2-\beta\theta}{\beta(1-\theta)}$$

$\pi^{II}_{io}=p_n(2-\beta\theta)$, $\pi^{II}_i=\frac{(2-\beta\theta)^2}{2+\beta-2\beta\theta}+2L$, *where* $p_n=\frac{2-\beta\theta}{2+\beta-2\beta\theta}+L$.

Region III *(r<2-βθ and* $L<\min(\frac{\beta(1-\theta)}{2+\beta-2\beta\theta},\frac{r}{2-\beta\theta}-\frac{2-\beta\theta}{2+\beta-2\beta\theta})$*):*

$$E_i(p)=\frac{r}{\beta(1-\theta)}[\ln\frac{1-L}{p_n(p_n-L)}+L(\frac{2}{p_n-L}-\frac{1}{p_n}-\frac{1}{1-L})+(1-\frac{1}{p_n-L})+\frac{r}{1-L}]+(1-L)-\frac{(2-\beta\theta)r}{\beta(1-\theta)}$$

$\pi^{III}_{io}=r$, $\pi^{III}_i=r+\beta\theta L$, *where* $p_n=\frac{r}{2-\beta\theta}$,

Region IV *(r≥2-βθ and* $L<1-\frac{r}{2+\beta-2\beta\theta}$*):*

$p^{IV}_i=1-L$, $p^{IV}_j=r$, $\pi^{IV}_{io}=[2+\beta(1-2\theta)](1-L)$, $\pi^{IV}_{jo}=r$, $\pi^{IV}_i=[2+\beta(1-2\theta)]-[2+\beta(1-3\theta)]L$, $\pi^{IV}_j=r+\beta\theta L$.

Region V *(r≥2-βθ and* $L \geq 1-\frac{r}{2+\beta-2\beta\theta}$*):*

$p^V_i=r$, $\pi^V_{io}=r$ and $\pi^V_i=r+\beta\theta L$.

The proof for Lemma 1 can be found in the appendix. Lemma 1 provides firms' equilibrium posted prices and profits under different regions of parameter values. An example of the equilibrium regions is shown in Figure 1 for r = 1.8 and L = 0.25.

[Figure 1 Here]

The equilibrium is in pure strategy for Region I, IV and V but is in mixed strategy for Region II and III. Detailed results relating to the price distributions in mixed strategy equilibrium can be found in the appendix.

As illustrated in Figure 1, when few consumers search for price information (β is small), the equilibrium will be in Region I. In this region, firms have no incentive to undercut each other's price because the size of competitor's weak loyal consumers who may switch ($w_{j\beta(1-\theta)}$) is small and the potential loss of revenue from a firm's own strong loyal consumers (s_i) and weak loyal consumers who do not search ($w_{i(1-\beta)}$) is large. Moreover, firms have an incentive to sell to the $w_{i(1-\beta)}$ segment because $r < 2$ by assumption and the size of this segment, which is $1-\beta$, is large. Therefore, both firms set $p_i = 1$ in equilibrium. The total profit for Firm i is a decreasing function of $\beta\theta$ while $2\beta\theta$ is the total size of consumers targeted by emails. This is because the email targeting market is more competitive than the posted prices market. As the result, the flow of consumers from the posted price market to the email targeting market reduces firms' profits.

When a large number of consumers search for prices but few of them are targeted by emails (β is large but θ is small), the equilibrium will be in Region II. In this region, the $w_{j\beta(1-\theta)}$ segment is large enough so that firms have incentive to undercut each other's price and the equilibrium result is similar to that in Raju, Srinivasan and Lal (1990) where firms adopt mixed strategy in pricing. Firms' expected equilibrium prices and total profits decrease as β increases. This is because as more consumers search for prices, firms compete more aggressively in the posted prices market and more consumers will be targeted by emailed discounts as well. We can also verify from Lemma 1 that, as consumer acceptance of email targeting (θ) increases, a firm's expected equilibrium price ($E_i(p)$) increases but its total profit, (π_i) decreases. On one hand, an increase in θ results in more consumers in the highly competitive email targeting market, which reduces a firm's profit. On the other hand, an increase in θ leaves smaller $w_{j\beta(1-\theta)}$ segments for firms to compete for, which leads to higher $E_i(p)$.

When a large number of consumers search for price information (β is large) and θ increases relative to its values in Region II, the equilibrium will be in Region III if the reservation price of strong loyal consumers (r) is large enough. Similar to Region II, firms also adopt mixed strategies in this region. Each firm's profit from its posted price is r, which is its guaranteed profit from the strong loyal segment. Firms' total profit increases when β and/or θ

increases as the revenue from the email targeting market increases. Unlike Region II, $E_i(p)$ can actually increase as β increases when θ is large enough. Firms have little incentive to compete in this case because a large θ implies a small switching segment $w_{j\beta(1-\theta)}$ and a large r implies a big loss of revenue from the strong loyal segment if a firm undercut its competitor to lure the potential switchers. Therefore, instead of lowering their prices as more consumers search prices, firms in this situation become more likely to charge r to secure its profit from the strong loyal segment and shun away from the more price sensitive "price searchers".[8] The change of $E_i(p)$ with respect to θ is similar to that in Region II and the same intuition applies. It is interesting to notice that in this region the profit and price implications of increasing consumer search (β) can actually be opposite to the conventional wisdom that lower search costs implies lower prices and profits (as discussed in detail in the introduction). We discuss this somewhat surprising result in greater detail later in this section.

As shown in Figure 1, if the number of consumers searching for price information is large (β is large) and their acceptance of email targeting (θ) further increases from its values in Region III, the equilibrium will be in Region IV. In this region, the $w_{j\beta(1-\theta)}$ segment is still sufficiently large so that one firm (Firm i) has incentive to undercut the price of the other firm (Firm j) to obtain those switchers. However, given Firm i's price at 1-L, the $w_{i\beta(1-\theta)}$ segment is not large enough for Firm j to lower its price to compete for. Instead, it is optimal for Firm j to sell only to its strong loyal customers in this situation. Firm j's profit increases with βθ as its revenue from email targeting increases and its profit from the posted price market is constant. Firm i's profit decreases with θ because a larger θ shifts more consumers to the more competitive email targeting market. When θ is small, Firm i's profit increases with β because larger β at small θ implies that Firm i can capture more consumers from its competitor with its posted price. However, when θ is large, Firm i's profit decreases with β because an increase in β under large θ moves more consumers from the posted price market to the lower priced email targeting market.

Finally, if the number of consumers searching for price information is large and their acceptance of email targeting (θ) is also high (both β and θ are large), the equilibrium will be in Region V. In this region, Both the $w_{j\beta(1-\theta)}$ and the $w_{i(1-\beta)}$ segments are so small that neither firm

[8] Technically speaking, in this case the probability mass at p_i=r increases in the mixed strategy equilibrium as β increases.

has incentive to undercut the price of the other firm to obtain the switching segment and each firm sells only to its strongly loyal customers. Both firms' profits increase with $\beta\theta$ as their revenue from email targeting increases and their revenue associated with the posted prices is constant.

It is easy to verify that, across all regions, firms' equilibrium posted prices and total profits are non-decreasing as r increases and/or L increases. The intuition behind it is very obvious because an increase in r increases the overall willingness to pay of consumers in the market and an increase in L reduces competition between firms.

Our main interest of the paper is to understand the joint impact of consumer search behavior and firms' targeting activities on market competition. Based on Lemma 1 and the discussion following it, we summarize the impact of consumer price search on firms' posted prices and total profits in the following proposition.

Proposition 1 (Impact of Consumer Price Search)*: If consumer acceptance to email targeting (θ) is small, firms' equilibrium posted prices are non-increasing and their equilibrium profits decrease as more consumers search for prices from competing firms (i.e. as β increases). However, if consumer acceptance to email targeting (θ) is sufficiently large, both firms' equilibrium posted prices and their equilibrium profits can increase as more consumers search for prices from competing firms.*

Proposition 1 can be proved using the results of Lemma 1. If consumer acceptance to email targeting (θ) is small, the equilibrium is in Region I when the size of the search segment (β) is small or is in Region II when β is large. From our early discussion, firms' posted prices are non-increasing and profits are decreasing with respect to β in both regions. Moreover, we also have $p^{II}_i < p^I_i$ and $\pi^{II}_i < \pi^I_i$ so that both equilibrium posted prices and profits decrease when the equilibrium shifts from Region I to Region II. Therefore, we can obtain the first part of Proposition 1. If θ is sufficiently large, as illustrated in Figure 1, the equilibrium will lie in Region III, IV or V when β is large. Based on our early discussion, firms' equilibrium posted prices and profits can both increase with β in those regions. This leads to the second part of Proposition 1.

Intuitively speaking, Proposition 1 is the result of two opposing effects of consumer price search activities on market competition. Obviously, there is a competition effect: an increase in consumer price search intensifies competition between firms. As more consumers search prices across competing firms, firms are more likely to undercut each other's posted prices. In addition, more consumers will be targeted by emails with even lower prices. This effect of consumer price search has a negative impact on firms' prices and profits, which is consistent with conventional wisdom.

However, there is also a price discrimination effect. An increase in consumer price search activities provides firms better information about those "price searchers" and gives firms the opportunity to price them differently from the other consumers. As a result, an increase in consumer price search enables firms to better price discriminate between their strong loyal consumers and weak loyal consumers. Consequently, it can lead to higher posted prices and profits. This effect becomes stronger as the consumer acceptance to email targeting (θ) increases. When θ is sufficiently large, the price discrimination effect will dominate the competition effect. Hence, firm's posted prices and total profits can both increase.

The first part of Proposition 1 confirms the conventional wisdom regarding the impact of consumer price search on firms' prices and profits. However, the second part of Proposition 1 contradicts conventional wisdom and shows that, in the presence of email targeting, an increase in consumer price search activities (or a reduction in consumer price search cost as $\frac{\partial \beta}{\partial C} \leq 0$) in a market can indeed increase firms' prices and profits. This result suggests that lowered consumer price search cost online (e.g. through using shopbots) may lead to either lower or higher observed online prices depending on the effectiveness of firms' email targeting (which is captured by θ). Thus, this proposition offers reconciliation to the seemingly divergent empirical findings regarding online retail prices as we mentioned in Introduction.

The Internet in general and shopbots in particular have drastically reduced consumer search costs for prices. Therefore, it will be interesting to compare firms' prices and profits under extreme values of β, which correspond to big differences in consumer search costs. We have the following corollary.

Corollary 1: *If both consumer acceptance to email targeting (θ) and consumer heterogeneity in willingness to pay (r) are sufficiently large, firms' posted prices and profits are higher in the case where a sufficiently large proportion of consumers search for prices ($\beta \to 1$) than in the case where no consumer searches for prices ($\beta = 0$).*

Corollary 1 is easy to verify. As shown in Lemma 1, the equilibrium falls in Region I at β=0. The corresponding posted prices and profits are p^I_i=1 and π^I_i=2. At $\beta\to1$ and $\theta\to1$, however, the equilibrium falls in Region V with corresponding posted prices and profits p^V_i = r and π^V_i = r + $\beta\theta$L. Therefore, we have $p^V_i > p^I_i$ and $\pi^V_i(\beta\to1,\theta\to1) \to r+L>2=\pi^I_i$ as $r\to2$. The same results can be obtained by comparing posted prices and profits in Region III or IV to Region I. Actually, as demonstrated in Figure 1, θ need not be very high for the equilibrium to be in Region III, IV or V. Therefore, Corollary 1 holds for a large range of parameter values of θ. Corollary 1 extends the conclusion in Proposition 1 by indicating that with the presence of email targeting, firms' prices and profits can increase not only with a marginal decrease but also with a dramatic decrease in consumer price search cost.

Proposition 1 and Corollary 1 reveal the impact of consumer price search on equilibrium outcomes with different levels of email targeting activities. We now look at the impact of θ, i.e. consumer acceptance of email targeting (or in other words, the effectiveness of targeting emails), on firms' posted prices and total profits. The results are given in Proposition 2 below.

Proposition 2 (Impact of Targeting Emails): *If the proportion of consumers searching prices (β) is small, firms' equilibrium posted prices are non-decreasing and their equilibrium profits decrease as more consumers are targeted by emails (i.e. as θ increases). However, if the proportion of consumers searching prices (β) is sufficiently large, both firms' equilibrium posted prices and their equilibrium profits can increase as more consumers are targeted by emails.*

Similar to Proposition 1, Proposition 2 can be proved using the results of Lemma 1. If β is sufficiently small, the equilibrium is either in Region I for all θ or in Region I then Region II as θ increases. In both cases, we have firms' posted prices non-decreasing and profits decreasing with respect to θ. If β is sufficiently large, the equilibrium will fall in Region III, IV or V when θ is large. From the discussion following Lemma 1, firms' equilibrium posted prices can increase in those regions as θ increases and their values can be higher than those in the cases where θ is small (i.e. in Region I or II). Also from Lemma 1, firms' equilibrium profits in those regions increase with θ as well.

The intuition behind Proposition 2 is similar to that for Proposition 1. First, there is a competition effect. An increase in targeting activities (θ) intensifies competition between firms because the email targeting market is more competitive than the posted prices market.

Obviously, this effect has a negative impact on firms' posted prices and profits. Second, there is also a price discrimination effect. An increase in targeting coverage further separates “price searchers” from strong loyal consumers and thus enables firms to better price discriminate between them. This price discrimination effect has a positive impact on firms' posted prices and profits. When consumer search activities are limited (β is small), the competition effect dominates the price discrimination effect since the email targeting market is very competitive compared to the posted prices market. This is because though the size of targeted consumers may be large due to high opt-in, the ability to price discriminate is small due to the small β.[9] Moreover, since most consumers do not search, the market for posted prices is not very competitive. However, when β is large, the price discrimination effect dominates the competition effect. Now the targeting market is not very competitive compared to the posted price market because a larger β leads to more competition even in the market of posted prices. Furthermore, the size of targeted consumers becomes large so that the benefit from price discrimination increases.

Propositions 1 and 2 indicate the importance of investigating the impact of consumer price search and firm targeting behavior using an integrated approach. The interaction between consumer price search and firms' email targeting is captured by $\beta\theta$ in our model. When this interaction is small (i.e. either β or θ is small), the results in the two propositions converge to similar conclusions as in the previous literature (Bakos 1997, Thisse and Vives 1988, Shaffer and Zhang 1995). However, when this interaction is strong (i.e. both β and θ are large), the opposite is true. In the context of the Internet, the interaction between consumer price search and firms' email targeting tends to be strong. On one hand, consumers empowered by Internet technologies such as shopbots can compare prices across several stores at one shot using a few "clicks". Consequently, their product preferences and price sensitivities are revealed to firms through their search activities and the resultant purchase decisions. On the other hand, firms equipped with emails servers and electronic databases can gather a large amount of consumer information online in real time and target consumers individually with negligible cost. This enables firms to price discriminate and helps mitigate (and even overcome) the competitive pressures on firm prices and profits. Therefore as suggested by Propositions 1 and 2, the implications of the

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9 When β is small, most people do not search so that their types cannot be identified.

reduced consumer price search cost on market competition can be very different from the predictions made by current theory that do not consider the interactions between shopbots and email targeting in the context of the Internet. As we explain in the introduction, our predictions are also consistent with the empirical findings of Clay et al. (2001), who have found that recently prices in the online book market have tended to rise.

Before concluding our analysis of the basic model in this section, we briefly discuss the welfare implications of consumer price search activities and firms' ability to target online. An interesting result is given in Corollary 2 below.

Corollary 2 *If a large number of consumers search prices and accept targeting emails (i.e. both β and θ are large), some consumers who do not receive targeted emails will not buy from either firm. Nevertheless, in this condition (i.e. when both β and θ are large), an increase in the number of consumers who search prices and/or accept targeting emails (i.e. as β and/or θ increase) can increase both total consumer welfare and firms' profits.*

Corollary 2 is directly obtained from Lemma 1 and Proposition 1 and 2. If the equilibrium is in Region I or II, all consumers are served in the market. Thus, consumer welfare increases (decreases) as firms' profits decreases (increases) in those regions. However, if the equilibrium is in Region III, IV or V (where both β and θ are large enough), some weak loyal consumers who do not receive targeting emails may not buy from either firm because at least one firm sets its posted prices at r with nonzero probabilities. Consequently, there are losses in total social welfare. As β and/or θ increase in those regions, more consumers will be served through the email targeting market and thus total social welfare increases. Consequently, it is possible for both firms and consumers to be better off when β and/or θ increase. For example, firms' profits increase with respect to β and θ in Region V. The total consumer welfare in this region is $W=2(r+\beta\theta-\pi^V_i)= 2\beta\theta(1-L)$. It increases with respect to β and θ as well.

Corollary 2 implies that consumers who do not search or do not like to receive targeting emails can be left out of the market by high prices, and this results in a loss of social welfare. However, given existing high levels of consumer search activities and firms' targeting efforts, any further increase in consumer price search and targeting emails may actually improve total consumer welfare and benefit firms simultaneously. It is interesting for the Internet policy makers that consumers who are dissatisfied with online privacy and therefore refuse to opt-in can be left out of the market when much of the market place is satisfied with the privacy standards and therefore opts in.

4. Extensions

In this section, we extend our basic model in several respects to obtain additional insights on the joint impact of consumer price search and firms targeting on market competition. First, in §4.1, we endogenize the level of consumer search and opt-in by explicitly modeling consumers' price search and opt-in behavior as determined by their costs of search and opt-in and the expected gains from doing so. In §4.2, we relax the symmetry assumption of firms and discuss the competitive implications of consumer price search and firms' email targeting in the context of asymmetric firms. Finally, in §4.3, we investigate the robustness of our main conclusions by relaxing the technical assumptions we make in the basic model.

4.1. Endogenous Price Search and Opt-In Decisions

In the basic model, we treat the number of consumers who search prices from competing firms (β) and consumers' opt-in decisions (θ) as exogenous. In this section, we extend the basic model to allow consumers' price search decisions as well as their decisions to opt into firms' email lists to be endogenous. These decisions are determined by trading off the costs and the expected gain from search and opt-in.

Assume that search costs are uniformly distributed on $[0,C_s]$ and opt-in costs are uniformly distributed on $[0,C_t]$ for consumers in the weak loyal segments. Let γ be the size of the price search segment among each firm's weak loyal consumers who are not targeted by emails and ϕ be the size of each firm's weak loyal consumers who are targeted by emails (i.e. opt in). γ corresponds to $\beta(1-\theta)$ and ϕ corresponds to $\beta\theta$ in our basic model. Let g_s and g_t be the expected gains from price search and opt-in excluding the costs of doing so, respectively. We have that $g_s = g_s(\gamma,\phi)$ and $g_t = g_t(\gamma,\phi)$. Obviously, γ is a function of C_s and $g_s(\gamma,\phi)$ and ϕ is a function of C_t and $g_t(\gamma,\phi)$. As detailed in the appendix, we can show that $\frac{\partial \gamma}{\partial C_s} \leq 0$, $\frac{\partial \phi}{\partial C_t} \leq 0$, $\frac{\partial \gamma}{\partial C_t} \geq 0$, and $\frac{\partial \phi}{\partial C_s} \leq 0$ in equilibrium. This leads to the following proposition.

Proposition 3*: The number of consumers who price search and the number of consumers who opt-in are non-decreasing as consumers' search costs decrease. As the costs of opt-in decrease, the number of consumers that accept firms' targeting emails is non-decreasing but the number of consumers that price search is non-increasing.*

The first part of proposition 3 further confirms the key intuition of the paper: consumer price search behavior and firms' targeting activities are highly correlated. Proposition 3 indicates that as the Internet reduces consumer search costs, not only more consumers will engage in price search but more consumers will also opt-in and can be targeted by competing firms. Consequently, when consumer search cost drastically reduces online, firms' profits and prices can actually increase as shown in the basic model.

The second part of proposition 3 shows that if the cost of opt-in reduces (e.g. consumers become less concerned about privacy violations), more consumers tend to accept targeting emails. As a result, firms have fewer consumers to compete for in the posted prices market. This reduces firms' incentive to compete in the market of post prices and thus the expected gain for the consumers who search but do not opt-in also decreases. Therefore, the volume of price searchers tends to decline as the opt-in cost reduces. This result appears to be consistent with lower than expected price search activities observed online as reported by Johnson et al. (2001). They found limited consumer search activities for books, CDs and travel sites. Internet firms in those product categories, such as Amazon, CDNow and Expedia, are well known for their extensive use of targeted emails.

4.2. Asymmetric Firms

So far, our discussion was limited to competition between symmetric firms. However, the main conclusions we derive from the basic model also apply to the case where the competing firms are asymmetric. To demonstrate this, we focus on the equilibrium corresponding to Region I and V in Lemma 1. Assume that the size of Firm 1's strong loyal segment is $\lambda_s>1$, the size of its weak loyal segment is $\lambda_w>1$, the reservation price of its strong loyal segment is $r_1>r$ with $\lambda_s r_1<\lambda_s+\lambda_w$, and the minimum price difference needed for its weak loyal consumers to switch is $L_1>L$. Let Firm 2 be the same as in the basic model. For the email targeting market, Firm 1 charges L_1 and Firm 2 charges 0 to Firm 1's weak loyal consumers in equilibrium. The resulting profits are $\lambda_w\beta\theta L_1$ for Firm 1 and 0 for Firm 2. Similarly, Firm 2 obtains a profit of $\beta\theta L$ and

Firm 1 obtains no profit from Firm 2's weak loyal consumers in the email targeting market. If $\beta \to 0$, the equilibrium for the posted prices is $p^I_1 = p^I_2 = 1$, which corresponds to Region I in the basic case. Firms' total equilibrium profits in this case are $\pi^I_1 = \lambda_s + \lambda_w[(1-\beta\theta(1-L)]$ and $\pi^I_2 = 2-\beta\theta(1-L)$. Both profits decrease with respect to β and θ, which are similar to our results from the basic model.

However, if $\beta \to 1$ and $\theta \to 1$, the equilibrium posted prices are $p^V_1 = r_1$ and $p^V_2 = r$, which corresponds to Region V in the basic model. Firms' total equilibrium profits in this case are $\pi^V_1 = r_1\lambda_s + \lambda_w\beta\theta L_1$ and $\pi^V_2 = r + \beta\theta L$. Both profits increase with respect to β and θ and p^V_i is higher than p^I_i. These results are similar to those in Proposition 1 and 2. Also, it is obvious that π^V_i can be higher than π^I_i when r_1 or r is sufficiently large, leading to the same conclusion as Corollary 1.

Comparing changes of firms' profits at $\beta = \theta = 1$ to $\beta = 0$, we have that

$$\Delta = (\pi^V_1|_{\beta=\theta=1} - \pi^I_1|_{\beta=0}) - (\pi^V_2|_{\beta=\theta=1} - \pi^I_2|_{\beta=0}) = (r_1-1)\lambda_s - (r-1) - \lambda_w(1-L_1) + (1-L) \quad (6)$$

It is easy to see that Δ increases with r_1, λ_s and L_1 but decreases with λ_w. The reason behind this result is as follows. Firm 1's gain from the price discrimination effect increases when r_1 or λ_s increases and its profit from email targeting increases with respect to L_1 as a larger L_1 leads to less competition. However, an increase in λ_w puts more consumers into the more competitive email targeting market and therefore reduces the firm's profit. Thus, the firm with a stronger market position (larger L) and a larger number of strong loyal consumers with higher willingness to pay will benefit more as consumer search cost drastically reduces and firms' targeting ability increases in the online world. However, a firm with only more weak loyal consumers will benefit less than its competitor or could be even worse off in this new competitive environment.

This result indicates that the value of loyalty is great in the online world and offers some support for online firms trying very hard to build a large customer base in the hopes of future competitive advantage. Our result however is particularly insightful as a warning that it is can be a disadvantage to have a large customer base if the customer base lacks strong loyalty. A larger customer base can be a competitive advantage only if it comes with a superior product or service that inspires high loyalty.

4.3. Relaxation of Technical Assumptions

We now relax several assumptions that we made to improve analytical tractability in the basic model. An important assumption in the basic model is that a firm's strong loyal consumers and weak loyal consumers who do not search (i.e. consumers in $s_{i,}$ and $w_{i(1-\beta)}$) have no incentive to opt-in for targeting emails. This assumption rules out firms' incentive to target those consumers. As we discussed in §2, this assumption holds as long as the cost of checking an email is nonzero. If this assumption does not hold (i.e. the cost of checking an email is zero), firms can target consumers in $w_{i(1-\beta)}$ with price at 1 in Region V and, unlike in the basic model, their profits will decrease with β in this region. However, even under this case, our results regarding Region III is unchanged because it is optimal for $w_{i(1-\beta)}$ consumers not to opt into firms' email lists in this equilibrium[10]. Thus, we can still find situations where firms' profits and prices increase with β and θ after relaxing this assumption.

In the basic model we assume that the cost of visiting a website of the firm a customer is loyal to is zero. If such cost is small but nonzero, the weak loyal consumers will not buy from the firm they are loyal to, if they expect the firm's price to be at 1 and the strong loyal consumers will not buy if they expect the firm's price to be at *r*. Consequently, the current equilibrium results no longer hold to Region I, IV and V. However, we can easily overcome this problem by slightly modifying our model as follows: Assume there are groups of consumers of size α_s and α_w in the strong loyal segments and weak loyal segments respectively. Consumers in α_s and α_w will buy from the firm offering lower prices (i.e. L=0 for them) and they always search. Obviously, firms will charge the opt-in consumers from α_s and α_w zero prices in the email targeting market. For the same reason as in the basic model, consumers who do not search have no incentive to receive targeting emails as long as the cost of checking an email is nonzero. This modified model allows consumers to incur a small cost to visit a website they are loyal to because neither firm will set price at 1 or r with probability 1 in equilibrium. Except that, the equilibrium results in this extended model are virtually the same as in the basic model for small

[10] If a consumer in $w_{i(1-\beta)}$ switches from "opt-out" to "opt-in", firms' posted prices will increase because Firm i is more likely to charge the posted price of p_i=r. This is because there are fewer weak loyal consumers in the posted price market. This implies that the consumer's surplus will be reduced if she buys in the posted price market after opting in. However she cannot gain in surplus by buying at the targeted prices, because Firm i will never charge her a targeting price below 1.

α_s and α_w. Indeed, our basic model can be regarded as a special case of this extended model with $\alpha_s \to 0$ and $\alpha_w \to 0$. All insights from the basic model remain the same. We adopt the simplified assumption in our basic model only to facilitate exposition.

Finally, we have assumed $\frac{1}{6} < L < \frac{1}{3}$ in the basic model. If $L \geq \frac{1}{3}$, firms will have no incentive to compete with each other and thus consumers never have motivation to search. If $L \leq \frac{1}{6}$, similar to Raju, Srinivasan and Lal (1990), explicit solutions for mixed strategy equilibrium corresponding to Region II and III are difficult to obtain. However, the results for other regions are the same even for this case. Therefore, the essential conclusions from the basic model remain robust.

5. Conclusion

The Internet has facilitated a number of tools such as shopbots and targeted emails. Relative to the traditional offline retailing, these tools reduce the costs of information transfer between firms and consumers by several orders of magnitude. Shopbots facilitate consumer price comparison across a number of online firms at fairly low search costs. Emails reduce the firms' cost of targeted communication with consumers. Since these tools have a major impact on how consumers receive competitive price information when making a purchase, they have important implications for price competition. In this paper, we investigate the implications of these tools for online price competition by modeling the interactive effects between them for the first time.

A key insight that we obtained from our analysis is that an increase in price comparison due to lower search costs provides firms the opportunity to learn about individual consumer preferences and price sensitivity. The Internet facilitates such learning and allows targeted marketing to consumers through emails. In contrast to the conventional wisdom that lower search costs on the Internet intensifies price competition and reduces profitability, we demonstrate that the competition intensification effect may be overwhelmed by the price discrimination effect achieved from superior targeting ability on the Internet. *This can raise average prices and profitability of firms despite the reduction in search costs*.

Our analysis offers interesting strategic insights for managers about how to address the competitive problems associated with low search costs on the Internet:

(1) It suggests that firms should invest in better technologies for personalization and targeted pricing so as to prevent the Internet from becoming a competitive minefield that destroys firm profitability. In fact we show that low search costs can facilitate better price personalization and can thus aid in improving the effectiveness of targeted pricing efforts.

(2) The analysis also offers guidelines on online customer acquisition efforts. The critical issue for competitive advantage is not in increasing market share per se, but in increasing the loyalty of the customers. While a larger share of very loyal customers reduces competitive intensity, surprisingly a larger share of customers who are not very loyal can be a competitive disadvantage. In order for customer acquisition to be profitable, it should be accompanied by a superior product or service that can ensure high loyalty.

(3) Investing in online privacy initiatives that assures consumers that their private information will not be abused other than to offer them "deals" is worthwhile. Such assurances will encourage consumers to opt into firm mailing lists. This facilitates successful targeting which in turn ameliorates the competitive threats posed by low search costs on the Internet.

(4) When the overwhelming majority of customers are satisfied with online privacy, the remaining privacy conscious customers who are not willing to pay a higher price to maintain their privacy will be left out of the market. While this may be of some concern to privacy advocates, it is interesting that total consumer welfare can be higher even if some consumers are left out.

Our primary analysis captures the competitive implications of the interaction between two institutions facilitated by the Internet: Shopbots and Emails. But our research question is more fundamental: What is the nature of competition in an environment with *low costs for both consumer search and firm-to-consumer personalized communications*? Our strategic insights may therefore be beneficially applied to offline businesses that can replicate such an environment. For example, offline retailers could have websites on which they post prices allowing for easy price comparisons. They can use tools such as frequency programs to create addressable databases that enable them to communicate with customers by direct mail or email (as many airlines and stores do).

This research however is only a first step towards understanding the competitive implications of the Internet. By design, we have focused on communication of only price information to control for other effects. Previous research however has indicated that the communicating product-related information over the Internet can increase the perceived differentiation among products and thus reduce competitive intensity (Zettelmeyer 1998). Moreover, Lal and Sarvary (1999) distinguish between products with primarily digital and non-digital attributes and show that competition may be reduced on the Internet for products with non-digital attributes. Future research therefore needs to evaluate the robustness of our insights by incorporating finer aspects of consumer search.

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Appendix

A.1. Proofs of Lemma 1 and Proposition 1 and 2

If $r<2-\beta\theta$ and $L \geq \frac{\beta(1-\theta)}{2+\beta-2\beta\theta}$ (Region I), then $p_i=1$ in equilibrium with $\pi_{io}=2-\beta\theta$. This is because neither firm would like to set $p_i=r$ as $r<2-\beta\theta$. Also, neither firm has incentive to undercut its competitor's price to get its $w_{\beta(1-\theta)}$ segment because the profit of doing so is $[2-\beta\theta+\beta(1-\theta)](1-L)$, which is less than $2-\beta\theta$ for $L \geq \frac{\beta(1-\theta)}{2+\beta-2\beta\theta}$.

If $r<2-\beta\theta$ and $L < \frac{\beta(1-\theta)}{2+\beta-2\beta\theta}$, then each firm has incentive to undercut the other's price in order to get the $w_{\beta(1-\theta)}$ segment from its competitor. This is because $[2-\beta\theta+\beta(1-\theta)](1-L)>2-\beta\theta$ now holds. This scenario is similar to the model discussed in Raju, Srinivasan and Lal (1990). The equilibrium involves mixed strategy because Firm i has incentive to undercut Firm j's price by L if p_j is high enough but has incentive to increase its price if p_j is low enough. The mixed equilibrium is derived below. The logic of the proof follows Raju, Srinivasan and Lal (1990).

First, let p_{n1} be the lowest price of Firm j that Firm i is willing to undercut. $p_{n1}>1-L$ must hold because $(1-2L)[2-\beta\theta+\beta(1-\theta)]<2-\beta\theta$ always holds as $L > \frac{1}{6}$ by assumption. This implies that rather than undercut $p_j=1-L$ by setting p_i below $1-2L$, Firm i is better off by setting $p_i=1$ to secure its own $w_{\beta(1-\theta)}$ segment and obtain $\pi_{io}=2-\beta\theta$. Since $p_{n1}>1-L$, it can be solved from $(p_{n1}-L)[2-\beta\theta+\beta(1-\theta)]=2-\beta\theta$. This leads to $p_{n1} = \frac{2-\beta\theta}{2+\beta-2\beta\theta} + L$.

Next, let p_{n2} be the lowest price Firm i will charge if such price does not undercut Firm j's price by L. Because Firm i can at least obtain $\pi_{io}=r$ by setting $p_i=r$, we have $p_{n2}(2-\beta\theta)=r$. Thus, $p_{n2} = \frac{r}{2-\beta\theta}$.

Now consider the case where $p_n=\max(p_{n1},p_{n2})=p_{n1}$, i.e. $\frac{r}{2-\beta\theta} - \frac{2-\beta\theta}{2+\beta-2\beta\theta} \leq L$. This is corresponding to Region II in Lemma 1. In this case, Firm i's price support is $p_i \in [p_n,1] \cup (p_n-L,1-L)$ because 1) neither firm would undercut price lower than p_n by L and 2) for any $p_j \leq 1-L$, Firm i would like to secure its own $w_{\beta(1-\theta)}$ segment by setting $p_i=p_j+L$ rather than undercut p_j by setting p_i below p_j-L. No probability mass can exist at 1-L because Firm i can undercut $p_j=1$ to obtain the $w_{j\beta(1-\theta)}$ segment only at p_i *below* 1-L. Also, probability mass cannot exist at p_n-L because Firm i will set $p_i=1$ rather than p_n-L if $p_j=p_n$. Denoting $H_i(p)=\Pr(p_i \geq p)$, we have the following equations from the profit-invariant nature of mixed strategy equilibrium.

$$\pi_{io}=p_i[(2-\beta)+\beta(1-\theta)H_j(p_i-L)], \text{ if } p_n \leq p_i \leq 1 \quad \text{(A1)}$$

$$\pi_{io}=p_i\{(2-\beta)+2\beta(1-\theta)H_j(p_i+L)+\beta(1-\theta)[1-H_j(p_i+L)]\}, \text{ if } p_n-L<p_i<1-L \quad \text{(A2)}$$

$\pi_{io}=p_i(2-\beta\theta)$ if $p_i=p_n$ (A3)

Thus, the equilibrium profit and price distribution for Firm i are $\pi_{io}=p_i(2-\beta\theta)$ and

$$H_i(p)=\frac{\pi_{io}}{\beta(1-\theta)(p-L)}-\frac{2-\beta}{\beta(1-\theta)}-1, \text{ if } p_n\le p_i\le 1; \quad \text{(A4)}$$

$$H_i(p)=\frac{\pi_{io}}{\beta(1-\theta)(p+L)}-\frac{2-\beta}{\beta(1-\theta)}, \text{ if } p_n-L<p_i<1-L. \quad \text{(A5)}$$

The probability mass at 1 is given by $q_1=H_i(1)$ and the probability mass at p_n is given by $q_n=H_i(1-L)-H_i(p_n)$. The expected equilibrium price of each firm can then be derived from its definition:

$$E_i(p)=\int_{p_n-L}^{1-L}-\frac{\partial H_i(p)}{\partial p}pdp+\int_{p_n}^{1}-\frac{\partial H_i(p)}{\partial p}pdp+q_n p_n+q_1.$$

The result is as provided in Lemma 1.

If $p_n=\max(p_{n1},p_{n2})=p_{n2}$, i.e. $L<\frac{r}{2-\beta\theta}-\frac{2-\beta\theta}{2+\beta-2\beta\theta}$, we have the Region III in Lemma 1. In this case, Firm i's price support is $p_i\in\{r\}\cup(p_n,1]\cup(p_n-L,1-L]$. Comparing to Region II, r is on the price support but there is no probability mass at p_n. This is because instead of setting $p_i=p_n$ Firm i will be better off setting $p_i=r$ in this case. There can be a probability mass at 1-L because Firm i can now charge $p_i=1-L$ in order to get the $w_{j\beta(1-\theta)}$ segment not served by Firm j when $p_j=r$. (A1)-(A5) still hold in this region by replacing (A3) with $\pi_{io}=p_i$ if $p_i=r$. Therefore, $\pi_{io}=r$ in equilibrium and the probability mass at 1-L is given by $q_{1-L}=H_i(1-L)-H_i(p_n)$. In addition, we have that

$\pi_{io}=p_i[(2-\beta\theta)+\beta(1-\theta)H_j(r)]$ if $p_i=1-L$, (A6)

which implies that $q_r=H_i(r)=\frac{\pi_{io}}{\beta(1-\theta)(1-L)}-\frac{2-\beta}{\beta(1-\theta)}-1$. Since $H_i(r)=H_i(1)$ obtained from (A4), there is no probability mass at $p_i=1$, i.e. the equilibrium price support is actually $p_i\in\{r\}\cup(p_n,1)\cup(p_n-L,1-L]$ in this case. Similar to Region II, the expected equilibrium price of each firm can then be derived from its definition:

$$E_i(p)=\int_{p_n-L}^{1-L}-\frac{\partial H_i(p)}{\partial p}pdp+\int_{p_n}^{1}-\frac{\partial H_i(p)}{\partial p}pdp+q_{1-L}(1-L)+q_r r,$$

which leads to the result reported in Lemma 1.

If $r\ge 2-\beta\theta$, Firm i will never charge a price below r if it cannot undercut the other firm's price by L to get the $w_{j\beta(1-\theta)}$ segment. If $L<1-\frac{r}{2+\beta-2\beta\theta}$, i.e. in Region IV, Firm i has incentive to set price at 1-L to get Firm j's $w_{\beta(1-\theta)}$ segment when $p_j=r$ because $(1-L)[2-\beta\theta+\beta(1-\theta)]>r$. However, Firm j has no incentive to further undercut

Firm i by setting p_j=1-2L because (1-2L)[2-βθ+β(1-θ)]<r as r≥2-βθ and $L > \frac{1}{6}$. Therefore, we have p_i=1-L, p_j=r, π_{io}=[2+β(1-2θ)](1-L) and π_{jo}=r in the equilibrium.

Finally, we are in Region V if r≥2-βθ and $L \geq 1 - \frac{r}{2+\beta-2\beta\theta}$. In this case neither firm has incentive to undercut the other firm for the $w_{j\beta(1-\theta)}$ segment by setting p_i below r because (1-L)[2-βθ+β(1-θ)]≤r. Therefore, p_i=r and π_{io}=r in the equilibrium.

Since the above regions are mutually exclusive and exhaust all possible values of parameters in the model, we have equilibrium results derived for the entire parameter space. The comparative statics of equilibrium profit w.r.t. the parameters in the model are easy to obtain by examining the signs of first order derivatives. So do the comparative statics of equilibrium price w.r.t. the parameters in the model for Region I, IV, and V. For Region II and III, the comparative statics of expected equilibrium price w.r.t. the parameters in the model are obtained by numerical examination because the expression of $E_i(p)$ given in Lemma 1 is very complicated. Since all parameters are confined to a closed range (1<r<2, $\frac{1}{6} < L < \frac{1}{3}$, 0≤β≤1, and 0≤θ≤1), the numerical analysis provides thorough results. The results regarding all such comparative statics are discussed following Lemma 1 and summarized in Proposition 1 and 2.

A.2. Proof for Proposition 3

Because of the symmetric nature of the two firms, we only focus on the symmetric case where $\gamma=\gamma_1=\gamma_2$ and $\phi=\phi_1=\phi_2$ in equilibrium. For any given γ and ϕ, the equilibrium results of Lemma 1 still hold by letting β(1- θ)=γ and βθ=ϕ. Let S_n be the surplus of a consumer in a firm's weak loyal segment who does not search, S_γ be the surplus of a consumer in a firm's weak loyal segment who searches but does not opt in targeting emails, and S_ϕ be the surplus of a consumer in a firm's weak loyal segment who opts in firms' targeting emails. Then by definition $g_s = S_\gamma - S_n$ and $g_t = S_\phi - S_\gamma$. It is obvious that g_s=0 if equilibrium happens at Region I, IV or V. Since g_s=0 implies γ=0 which leads to β=0 or θ=1, from Lemma 1, Region I and V can be in equilibrium but Region IV cannot. This is consistent with the claim that $\phi=\phi_1=\phi_2$ in equilibrium because Region IV is the only region where firms' strategies can be asymmetric.

For equilibrium at Region II, we have that S_n=1-E(p), S_ϕ=1-L. To calculate S_γ, notice that a consumer in γ_i switches to buy from Firm j if p_i-p_j>L but she also incurs a disutility L for doing so. Therefore,

$$S_\gamma = 1-\{\int_{p_n-L}^{1-L} p\frac{-\partial H_i(p)}{\partial p}dp + \int_{p_n}^{1} pH_j(p-L)\frac{-\partial H_i(p)}{\partial p}dp + \int_{p_n}^{1}[\int_{p_n-L}^{p_i-L}(p_j+L)\frac{-\partial H_j(p_j)}{\partial p_j}dp_j]\frac{-\partial H_i(p_i)}{\partial p_i}dp_i$$
$$+q_n p_n + H_i(1-L)q_1 + [\int_{p_n-L}^{1-L}(p_j+L)\frac{-\partial H_j(p_j)}{\partial p_j}dp_j]q_1\}.$$

For Region III, we still have S_ϕ=1-L. $S_n = 1-[\int_{p_n-L}^{1-L} p\frac{-\partial H_i(p)}{\partial p}dp + \int_{p_n}^{1} p\frac{-\partial H_i(p)}{\partial p}dp + q_n p_n + q_r]$ in this case because if p_i=r consumers in γ will not buy. Similar to Region II, we have

$$S_\gamma = 1 - \{\int_{p_n-L}^{1-L} p \frac{-\partial H_i(p)}{\partial p} dp + \int_{p_n}^{1} pH_j(p-L)\frac{-\partial H_i(p)}{\partial p} dp + \int_{p_n}^{1} [\int_{p_n-L}^{p_i-L} (p_j+L)\frac{-\partial H_j(p_j)}{\partial p_j} dp_j]\frac{-\partial H_i(p_i)}{\partial p_i} dp_i$$
$$+ q_{1-L}(1-L) + H_i(1-L)q_1 + [\int_{p_n-L}^{1-L}(p_j+L)\frac{-\partial H_j(p_j)}{\partial p_j} dp_j] q_1\}.$$

Since both S_γ and S_n are functions of γ and ϕ, g_s and g_t are also functions of γ and ϕ. Therefore, we have that $\gamma=\gamma(C_s,\phi)$ and $\phi=\phi(C_t,\gamma)$ in reduced forms. Thus,

$$\frac{\partial \phi}{\partial C_s} = \frac{\partial \phi}{\partial \gamma}\frac{\partial \gamma}{\partial C_s}, \quad \text{(A7)}$$

$$\frac{\partial \gamma}{\partial C_s} = \frac{\partial \gamma}{\partial C_s}|_\phi + \frac{\partial \gamma}{\partial \phi}\frac{\partial \phi}{\partial C_s} = \frac{\partial \gamma}{\partial C_s}|_\phi + \frac{\partial \gamma}{\partial \phi}\frac{\partial \phi}{\partial \gamma}\frac{\partial \gamma}{\partial C_s}, \quad \text{(A8)}$$

$$\frac{\partial \gamma}{\partial C_t} = \frac{\partial \gamma}{\partial \phi}\frac{\partial \phi}{\partial C_t}, \quad \text{(A9)}$$

$$\frac{\partial \phi}{\partial C_t} = \frac{\partial \phi}{\partial C_t}|_\gamma + \frac{\partial \phi}{\partial \gamma}\frac{\partial \gamma}{\partial C_t} = \frac{\partial \phi}{\partial C_t}|_\gamma + \frac{\partial \phi}{\partial \gamma}\frac{\partial \gamma}{\partial \phi}\frac{\partial \phi}{\partial C_t}. \quad \text{(A10)}$$

To prove Proposition 3, we first claim that $\frac{\partial \gamma}{\partial C_s}|_\phi \le 0$. The proof is as follows. By definition, $\gamma = \int_0^{\min(g_s(\gamma,\phi),C_s)} \frac{1}{C_s} dc - \phi$. Thus, $\frac{\partial \gamma}{\partial C_s}|_\phi = \frac{\partial \gamma}{\partial C_s}|_{g_s} + \frac{\partial \gamma}{\partial g_s}|_{C_s} \frac{\partial g_s}{\partial \gamma}\frac{\partial \gamma}{\partial C_s}|_\phi$. In equilibrium, $\frac{\partial g_s}{\partial \gamma} \le 0$ must hold. Otherwise, if $\gamma=\gamma_0$ is in equilibrium and $\frac{\partial g_s}{\partial \gamma} > 0$ at $\gamma=\gamma_0$, more consumers would engage in price search (i.e. γ would be larger than γ_0) because the expected gain from search increases as γ increases. This contradicts that γ_0 is in equilibrium. Hence, equilibrium cannot exist at $\frac{\partial g_s}{\partial \gamma} > 0$. Because $\frac{\partial g_s}{\partial \gamma} \le 0$, $\frac{\partial \gamma}{\partial C_s}|_{g_s} \le 0$ and $\frac{\partial \gamma}{\partial g_s}|_{C_s} \ge 0$, we must have $\frac{\partial \gamma}{\partial C_s}|_\phi \le 0$ in equilibrium. Similarly, we also have $\frac{\partial \phi}{\partial C_t}|_\gamma \le 0$ in equilibrium because (i) $\frac{\partial \phi}{\partial C_t}|_\gamma = \frac{\partial \phi}{\partial C_t}|_{g_t} + \frac{\partial \phi}{\partial g_t}|_{C_t} \frac{\partial g_t}{\partial \phi}\frac{\partial \phi}{\partial C_t}|_\gamma$, (ii) $\frac{\partial \phi}{\partial C_t}|_{g_t} \le 0$, (iii) $\frac{\partial \phi}{\partial g_t}|_{C_t} \ge 0$, and (iv) $\frac{\partial g_t}{\partial \phi} \le 0$ must hold in equilibrium (this can be proved using the similarly argument as in the proof of $\frac{\partial g_s}{\partial \gamma} \le 0$).

Next, we claim that $\frac{\partial \gamma}{\partial \phi} \le 0$. The proof is as follows. From $\gamma = \int_0^{\min(g_s(\gamma,\phi),C_s)} \frac{1}{C_s} dc - \phi$, we have that $\frac{\partial \gamma}{\partial \phi} = \frac{\partial \gamma}{\partial g_s}|_{C_s} (\frac{\partial g_s}{\partial \gamma}\frac{\partial \gamma}{\partial \phi} + \frac{\partial g_s}{\partial \phi}) - 1$. Using the expressions of S_γ and S_n derived early, we can numerically verify that

$\frac{\partial g_s}{\partial \phi} \leq 0$ in equilibrium. The numerical analysis is thorough because all parameters are confined in finite interval. Since $\frac{\partial g_s}{\partial \phi} \leq 0$, $\frac{\partial \gamma}{\partial g_s}|_{C_s} \geq 0$ and $\frac{\partial g_s}{\partial \gamma} \leq 0$ in equilibrium, we must have $\frac{\partial \gamma}{\partial \phi} \leq 0$.

Moreover, we claim that $\frac{\partial \phi}{\partial \gamma} \geq 0$. The proof is as follows. To examine $\frac{\partial \phi}{\partial \gamma}$, notice that for an $\Delta\gamma$ increase in γ, the corresponding increase in ϕ is $\Delta\phi = \Delta\gamma \int_0^{\min(g_t(\gamma+\Delta\gamma,\phi+\Delta\phi),C_t)} \frac{1}{C_t} dc + \gamma \int_{\min(g_t(\gamma,\phi),C_t)}^{\min(g_t(\gamma+\Delta\gamma,\phi+\Delta\phi),C_t)} \frac{1}{C_t} dc$. The first term in the right side of the expression is an increase in ϕ due to more consumers engaging in price search. The second term in the right side of the expression is a change in ϕ due to a change in g_t resulting from a change in γ. Therefore, $\frac{\partial \phi}{\partial \gamma} = \frac{\partial(\gamma g_t)}{C_t \partial \gamma} + \frac{\gamma}{C_t} \frac{\partial g_t}{\partial \phi} \frac{\partial \phi}{\partial \gamma}$. We can numerically verify that $\frac{\partial(\gamma g_t)}{\partial \gamma} \geq 0$ for the entire parameter space. Because we also have $\frac{\partial g_t}{\partial \phi} \leq 0$ in equilibrium, we must have $\frac{\partial \phi}{\partial \gamma} \geq 0$.

Finally, because $\frac{\partial \gamma}{\partial C_s}|_\phi \leq 0$, $\frac{\partial \gamma}{\partial \phi} \leq 0$, and $\frac{\partial \phi}{\partial \gamma} \geq 0$ in equilibrium, from (A8) we must have $\frac{\partial \gamma}{\partial C_s} \leq 0$. Then we must also have $\frac{\partial \phi}{\partial C_s} \leq 0$ from (A7). Similarly, we must have $\frac{\partial \phi}{\partial C_t} \leq 0$ from (A10) because $\frac{\partial \phi}{\partial C_t}|_\gamma \leq 0$, $\frac{\partial \gamma}{\partial \phi} \leq 0$, and $\frac{\partial \phi}{\partial \gamma} \geq 0$ in equilibrium. As a result, $\frac{\partial \gamma}{\partial C_t} \geq 0$ must also hold according to (A9).

Figure 1: Equilibrium Regions (r = 1.8, L = 0.25)