An Economic Model of Portal Competition under Privacy Concerns

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ABSTRACT

Due to inherent privacy concerns, online personalization services such as those offered through toolbars and desktop widgets are characterized by "no-free-disposal" (NFD) property, in that more services are not necessarily better for the consumer. There are two defining characteristics of this market: First, these services are "free" as firms value consumers' preference information shared for personalization; second, while some firms provide toolbars of a fixed-length as a take-it or leave-it offer, many others offer consumers the option of choosing a subset of the services offered. Our findings suggest that in a fixed-services duopoly where firms are endowed with sufficiently different marginal values for information (MVIs), the high MVI firm caters to convenience seekers in the market while the low MVI firm serves a portion of largely privacy seeking consumers in equilibrium; if the duopoly were characterized by sufficiently high MVIs, firms would minimize differentiation and offer the same number of services. However, when two high-MVI firms pursue variable-services strategy, there is a unique symmetric equilibrium that maximizes consumer surplus. Counter to intuition, some very high-MVI firms may prefer the consumer-surplus maximizing strategy of offering the full set of variable services over the fixed-services strategy, thus maximizing both consumer and social welfares. Our results lead to important managerial and policy implications and interesting extensions to the existing location models.

Categories and Subject Descriptors

K.6.0 [**Management of Computing and Information Systems**]: General – *economics.*

General Terms

Management, Economics, Theory, Legal Aspects.

Keywords

Personalization, privacy, spatial competition, Nash-equilibrium, welfare analysis.

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1. INTRODUCTION

As a recent Federal Trade Commission (FTC) workshop suggests, a set of technologies that have begun to raise consumer concerns of privacy are browser-embedded toolbars, while some groups characterized this as spyware, many others tout toolbar-enabled personalization as the future of online services (FTC 2004). A toolbar is a Browser Helper Object (BHO), wherein once downloaded and embedded it has the ability to monitor and report usage information (including Web sites visited, information filled in online forms, etc.) as well as to tailor future online interactions. More recently, Google's Deskbar, Microsoft's Live and Yahoo!'s Konfabulator technologies have begun to offer these services right from the desktop and is expected replace current Web-based static personalization. Once embedded, firms can disallow consumers from turning off select features, thus consumers may need to remove the entire toolbar (and hence forgo all personalization) if their comfort level in sharing information is below that of the amount acquired by the toolbar. As the FTC continues to assess its position on these technologies, toolbars have become ubiquitous with every online portal (Yahoo!, MSN, AOL, etc.) and many large online firms (eBay, Amazon, etc.) offering them, e.g. currently over 618 Million searches originate from consumers using toolbars. Thus, one important objective of this paper is to investigate the regulatory implications regarding the allowance of such personalization technologies through a social welfare analysis.

The operational basis for online firms that provide toolbars and other methods of personalization in competition for consumer information is unique. Personalization services are entirely free of charge to the consumers; portal-like firms rely on their ability to sell browsing profiles to advertisers and targeted marketers (Dewan, et al. 1999) while e-tailers use information acquired for personalization to manage their own inventory, marketing goals, and to enhance customer satisfaction and loyalty (Shankar et al. 2002). Indeed, the FTC also acknowledges the legitimate use of consumer information by businesses provided that such usage can also be beneficial to consumers (See workshop report (FTC 2003)). From the consumer behavior perspective, online personalization is an example of goods with "no free disposal" (NFD) property, an economic classification of goods meaning that more of the good is not necessarily better. Recent work on pricing access services online (Essegaier, et al. 2002), observes, "Unlike physical goods for which ''free disposal'' is always an option and more is, in general, always better, service delivery is intrinsically participatory. Participation requires time commitment and physical effort on the part of consumers. Thus, there is no free disposal for service, and time cost and physical efforts limit the effectiveness of price incentives in altering consumer usage habit." One other important cost intrinsically related to the usage of personalization services is the privacy costs that individuals incur when sharing their preference and usage information needed for tailoring services to their tastes (Volokh 2000). Therefore even if free of cost, not all consumers will prefer all services offered by the firm. This property poses many unique challenges to online firms and portals who incur costs of creating personalized services so as to acquire consumers' usage information. Thus, our paper examines a competitive market for privacy where firms have to strategically choose their level of personalization services offering for acquiring consumer information.

Further, we incorporate the possibility of online firms being similarly or differently endowed in their capacity to generate revenue or lower operating costs from mining and using consumer information and thus they may vary in the value placed on consumer information. For example, many large firms such as AOL and MSN do not simply resell their information, but they operate their own advertising networks with their own profiling technologies as well. On the other hand, many smaller firms and portals mostly act as a carrier of other's advertising networks such as from DoubleClick (DART network) and Atlas (Atlas Suite). Offering personalization is not costless but these technologies are ubiquitous and available to all, hence firms need to investigate their optimal service offerings when their competitors can also potentially offer identical services. Firm strategies in this regard have largely been unexplored in academic research, particularly given the NFD nature of consumers' utility from personalization amidst their privacy concerns. In order to study the welfare implications of allowing a toolbar-like technology, we examine the market equilibrium when one or both firms offer variable services wherein a consumer is allowed the option to choose the full set of services in the toolbar or disable some services based on their privacy concerns. We contrast this with equilibrium findings when firms offer a fixed set of services wherein consumers are made a take-it or leave-it offer to embed a toolbar of fixed-length or to not use it all. The latter scenario is of particular relevance to privacy-groups that are concerned about the possibility of consumers sharing more information than they would ideally want.[1]

2. MODEL

Our model develops the strategic interactions between online firms and consumers of personalization services. Consumers engage in a privacy calculus in their decision to use personalization services as they incur privacy costs in sharing information needed for this activity (Culnan and Bies 2003). This willingness to share information is based on the consumer's perceived benefits of disclosure balanced with its risks (Derlega et al. 1993). Consumer behavior in this context has been modeled by prior research (Chellappa and Shivendu 2006) as a function of consumers' marginal value for personalization p and their coefficient of information privacy concerns r given by $u(i,s,p,r) = ps - ri^2$, where s is the level of personalization services consumed and i is the preference information that needs to be shared by the consumer in order for services to be personalized.

The number of personalized services that can be created from a unit of information is commonly a function of the prevalent personalization and data mining technologies (Raghu et al. 2001; Winer 2001). One can view this as a production function wherein some technology determines how many services (s) can be created from some information (i) that is provided. While theoretically more than one service can be created for every unit of information shared, it is generally accepted that this technology is still evolving despite significant advances in information acquisition (Chen and Hitt 2002). Hence we assume that one unit of preference information shared provides one unit of corresponding personalized service $(i = s)$. Since the firms determine the number of personalization services to be offered in the market, and through the usage of services the consumers determine how much information they will share, we can write a consumer c's utility as a function of personalization services consumed:

$$u_c(s,p,r) = p_c s - r_c s^2 \tag{1}$$

It is important to note two salient aspects of consumption here: First, services are provided for free. Consumers do not pay any price to the firm. Second, more services are not necessarily better. Each consumer has an optimal service level (s_c^*) that she prefers over all other service levels. The latter (and its quadratic form) is a characteristic of a class of economic goods with the "no free disposal" property which implies that individuals derive disutility from consuming additional quantities beyond their satiation level, e.g., hikers prefer to carry an optimal sized water container rather than very small or large bottles (Nahata et al. 2003).

Note that the utility function is non-monotonic (an inverted-U function) in services consumed, and is characterized by the two levels, the utility maximizing $s_c^* = \arg\max_s u_c(s,p,r)$ and break-even $\left(s_c^0 : u(p,r,s)|_{s=s_c^0} = 0\right)$ service levels respectively. For the utility function described by equation (1), we can see that $s_c^0 = \frac{p_c}{r_c}$ and $s_c^* = \frac{p_c}{2r_c}$. The ratio $\frac{p}{r}$ is known as the consumers' personalization for privacy (p4p) ratio and is a critical parameter for analysis of consumer behavior as it determines both their indifference and optimal service levels. Empirical research finds that consumers may vary in their value for personalization and concerns for privacy (Chellappa and Sin 2005). Without loss of generality, we consider a market where consumers are uniformly distributed in their p4p ratio given by $\frac{p}{r} \sim U[0,b]$. This also allows us to represent the two consumer-behavior characterizing levels along the same dimensions given by $s_c^0 \sim U[0,b]$ and $s_c^* \sim U\left[0,\frac{b}{2}\right]$. We shall generally refer to consumers with low p4p ratios as privacy-seekers and those with high p4p values as convenience-seekers.

[1] A full literature review is available from the authors on request.

2.1 Online Firms' Strategies

Firms vary in their ability to use consumer information by virtue of the extent to which this information can be exploited to their own purposes, represented by their marginal value for information (MVI). For example, portals such as Yahoo! and AOL that run their own advertising networks do not simply resell usage/preference information; rather they have a portfolio of advertising related products unlike portals such DogPile and AskJeeves. Yahoo! Search Marketing division (previously part of Overture) offers products such as Search Optimizer and Marketing Console that are geared towards small to medium firms, and provides a fully customized advertising program for firms that have a budget of over \$10,000 per month. Similarly, retailers like Amazon.com that carry many product categories and with sophisticated cross-selling strategies have greater marginal values for preference information than firms that sell one type of product or use their service to host advertisements.

Offering personalization services is not costless; either firms incur their own costs of building a toolbar, or they incur licensing and technology costs from buying from firms such as BestToolBars.net and ezToolbar.com. In addition, firms offering personalization also incur costs of licensing content, building trust through alliances with trusted third-parties (e.g., TRUSTe, WebCPA, Verisign), and implementing security mechanisms to comply with FTC requirements (FTC 2000) and special legislative requirements such as Children's Online Privacy Protection Act (COPPA) and Health Insurance Portability and Accountability Act (HIPPA) as well (Bloom et al. 1994; Scott 1999; Anonymous 2001). Hence we construct a firm's profit function as

$$\pi_j = \sigma_j A(s) - s^2 \tag{2}$$

where σ_j is the marginal value for information of a firm j and $A(s)$ is the aggregate information acquired from the usage of s personalization services. In this paper we assume that firms incur similar costs in offering services but are heterogeneous in their marginal values for information. Hence we drop the firm specific cost coefficient discussed elsewhere (Chellappa and Shivendu 2006). The identical cost function not only rules out a trivial explanation that any difference in firm strategies is due to differences in costs, but is also consistent with the ubiquitous availability and open-standard nature of personalization technologies. The ability to use information however is indeed a function of firms' business strategies and endowments and may affect their overall personalization offerings. Note that no exogenous assumption is made on the relative MVI's of the firms in the market.

Further, the online firms have the option of offering the personalization toolbar in one of the following two ways:

1. A toolbar of fixed length – where the firm contracts to personalize a fixed number of services and will monitor and acquire information corresponding to the entire set of services. The consumer is faced with a take-it or leave-it offer where they will use as long as the utility is non-negative for the service level, i.e., $s \in \left(0, s_c^0\right]$. A9.com's (affiliated with Amazon.com) toolbar is a classic example of this approach where a consumer has to agree to all the information being monitored (which is fully disclosed in the firm's privacy policy) or to not use the toolbar at all. Through out the paper we shall refer to this as the fixed-services strategy.
2. Toolbars of variable lengths – where the firm offers a toolbar with its full list of personalizable services and allows consumers to choose a subset of services. In this case when consumers vary in their p4p tradeoffs, each consumer will use a different services level according to her optimal level s_c^* if available, else the level provided by the firm (formally $\min\left\{s_c^*, s\right\}$). Many toolbars including Google and Yahoo! follow this approach where consumers have the option to turn off personalization based on increasingly sensitive information, e.g., the PageRank (called Web Rank in Yahoo!) feature can be removed when using Google toolbar services. We shall refer to this as the variable-services strategy.

3. COMPETITION IN A DUOPOLY

We consider a duopoly where the two firms have MVIs given by σ_1 and σ_2. We need not make any assumptions about the relative values of the two MVIs at this juncture and as such they could represent two portals that have their own advertising and partner networks (high MVI), two information reselling portals (low MVI) or one of each. We consider a game in which both firms simultaneously choose their respective service levels $s_1 \in S_1$ and $s_2 \in S_2$. Note that the strategy spaces are also bounded by b $(S_1, S_2 = [0, b])$ as no consumer would use beyond this level and hence no firm will ever consider a strategy of offering services beyond this limit. Hence our personalization market can be characterized as a linear one where each consumer's location or ideal service level s_c^* is uniformly distributed from 0 to $\frac{b}{2}$. If a firm offers a certain service level s_1 at some distance x from the ideal point of a consumer, we can see that the disutility given by $\left| u_c\left(s_c^*\right) - u_c\left(s_1\right) \right|$ will be rx^2. In other words, consumers suffer a convex transportation cost along the lines of D'Aspremont et al. (1979) for which equilibrium in locations exists under certain condition. While firms incur convex costs of locating themselves on the line (normally ignored in purely spatial models), the zero-marginal costs and zero versioning costs of services (a lower service-level can be offered costlessly once a toolbar of higher services is built) combined with the NFD property create unique competitive situations non-existent in physical goods markets. While the fixed services approach appears to be structurally similar to physical goods model setup (i.e., once a firm has located, all consumers have to buy from that point), the variable-services strategy creates a unique possibility wherein if the firm offers a service level s_1, he can costlessly serve all consumers with $s_c^* < s_1$ at their ideal levels. Again, we do not assume *a priori* as to whether the market is covered (mostly the case in spatial models) or not, i.e., consumers do not have infinite reservation. In view of these differences, it is not clear if any equilibrium possibilities exist at all, hence this is an interesting model to analyze from a location model perspective as well.

3.1 Market Outcomes when Both Portals Offer Fixed Services

We first consider the case when both firms offer a toolbar of fixed length, i.e., a take-it or leave-it offer where consumers who pick up the contract agree to the acquisition of a fixed amount information on their usage. In this case, consumers will use the level of service that is provided so long as their utilities are non-negative. In the duopoly, a consumer will choose Portal 1 if her utility from using s_1 is greater than that from using s_2 $(u_c(s_1) > u_c(s_2))$. First consider the case when Portal 1 might offer fewer services than Portal 2 ($s_1 < s_2$, case "a"). A consumer will derive a higher utility from using services provided by Portal 1 if:

$$ps_1 - rs_1^2 > ps_2 - rs_2^2 \Rightarrow \frac{p}{r}(s_1 - s_2) > s_1^2 - s_2^2 \qquad (3)$$

And since $s_1 < s_2$, equation (3) implies $\frac{p}{r} < s_1 + s_2$. Notice that consumers with $s_c^0 < s_1$ would not use any services at all, therefore consumers whose break-even service level $s_c^0 \in [s_1, s_1 + s_2)$ would use Portal 1's services and the remaining consumers $s_c^0 \in [s_1 + s_2, b]$ would use Portal 2's services. By symmetry, we know that if Portal 1 offers more services than Portal 2 ($s_1 > s_2$, case "c"), consumers with $s_c^0 \in [s_1 + s_2, b]$ will use Portal 1's services. If both portals offer the same level of service level ($s_1 = s_2$, case "b"), then given that consumers are indifferent between the two portals, Portal 1 will get half the market of all consumers using the services, i.e. half of the consumers whose break-even service level are $s_c^0 \in [s_1, b]$. Therefore, the amount of information that a portal acquires depends upon both his level of service and its magnitude relative to that of the second portal. We can formally write Portal 1's profit functions[2] as

$$\pi_1^F = \begin{cases} \pi_{1a}^F = \sigma_1 \int_{s_1}^{s_1+s_2} s_1 U(s_c^0) d(s_c^0) - s_1^2 & \text{if } (s_1 < s_2) \\ \pi_{1b}^F = \frac{1}{2}\sigma_1 \int_{s_1}^{b} s_1 U(s_c^0) d(s_c^0) - s_1^2 & \text{if } (s_1 = s_2) \\ \pi_{1c}^F = \sigma_1 \int_{s_1+s_2}^{b} s_1 U(s_c^0) d(s_c^0) - s_1^2 & \text{if } (s_1 > s_2) \end{cases}$$

By symmetry, we can construct Portal 2's profit function and notice that the payoff functions of both firms are discontinuous in the service space. The discontinuity could lead one to believe that there may be no equilibrium in pure strategies at all and that only mixed strategies equilibria exist. However, for our analyses, we consider only pure strategy equilibria for two reasons: First, mixed strategies severely limit the explanatory power of the model; second, work by Dasgupta and Maskin (1986) suggests that it is not the discontinuity itself, but rather failure of the payoff functions to be quasi-concave that is the reason for the non-existence of equilibrium in pure-strategies. They propose that under certain conditions (quasi-concavity, upper semi-continuity and graph continuity of the payoff functions), even a game with functions that have limited continuity can possess a pure-strategy Nash equilibrium. Later work has argued these conditions are far too restrictive and only certain conditions[3] on the aggregator function need to be satisfied for a pure strategy equilibrium to exist (Baye et al. 1993).[4]

Thus, we go on to develop the strategic interactions between the two portals so as to find pure-strategy equilibria. Portal 1's strategy is a best response to the strategy of Portal 2 if it maximizes $\pi_1^F\left(\max\{\pi_{1a}^F, \pi_{1b}^F, \pi_{1c}^F\}, s_2\right)$ in the strategy space S_1 for any given s_2. In considering the best response of Portal 1, not only does he need to decide on the service level but he also needs to determine whether to offer a service level that is lower than, equal to or greater than the competing portal. By symmetry, we can see that Portal 2 also needs to make a similar decision in responding to services offered by Portal 1. Independently, profits in their defined regions are all strictly concave, hence interior optima are candidates for equilibrium outcomes. However, note that for some firm parameters the functions do not attain their maximum within the defined regions, e.g., when $\sigma_1 > 2b$, π_{1a}^F is still increasing as s_1 approaches s_2, implying that this firm type will attempt to "undercut" Firm 2 by offering slightly more services. Hence when a firm's MVI is greater than $2b$, offering services fewer than those offered by his competitor can never be a profit-maximizing strategy in equilibrium. Similarly, when a competitor offers a service level $s_2 \geq \frac{b\sigma_1}{2b + 3\sigma_1}$, irrespective of his own MVI, it is not optimal for Firm 1 to offer more than Firm 2 as π_{1c}^F is monotonically decreasing in s_1; hence region c cannot be an equilibrium candidate for this particular firm pair. Therefore, if the Nash equilibrium pair is given by s_1^{F*}, s_2^{F*}, then from Firm 1's perspective and for any Firm 2 there *might be*

1. An asymmetric equilibrium where Firm 1 offers *fewer* services than Firm 2, given by $s_1^{F*}, s_2^{F*}\left(s_1^{F*} < s_2^{F*}\right) = \left\{\frac{\sigma_1}{2b}s_2^{F*}, s_2^{F*}\right\}$ and Firm 1's MVI is $\sigma_1 < 2b$.
2. An asymmetric equilibrium where he offers *more* services than Firm 2, given by $s_1^{F*}, s_2^{F*}\left(s_1^{F*} > s_2^{F*}\right) = \left\{\frac{\left(b - s_2^{F*}\right)\sigma_1}{2(b + \sigma_1)}, s_2^{F*}\right\}$ and Firm 1's MVI $\sigma_1 < \frac{2bs_2^{F*}}{b - 3s_2^{F*}}$.
3. A symmetric equilibrium where he offers the same services as Firm 2, given by $s_1^{F*}, s_2^{F*}\left(s_1^{F*} = s_2^{F*}\right) = \left\{s_2^{F*}, s_2^{F*}\right\}$ for any MVI of Firm 1.

[2] Alphabets in the subscripts of the profit functions correspond to the respective cases regarding the relative service levels of the portals as discussed above.

[3] The sufficient conditions are *Diagonal Transfer Continuity* and *Diagonal Transfer Quasiconcavity.*

[4] A technical appendix containing complete proofs of lemmas in this paper is available from the authors upon request.

In order for the service-pair $\{s_1^{F*}, s_2^{F*}\}$ to be an equilibrium candidate, we need $\max\{\pi_1^F(., s_2^*)\} = \pi_{1a}^F(s_1^{F*})$ and $\max\{\pi_2^F(s_1^*, .)\} = \pi_{2c}^F(s_2^{F*})$ in case 1, $\max\{\pi_1^F(., s_2^*)\} = \pi_{1c}^F(s_1^{F*})$ and $\max\{\pi_2^F(s_1^*, .)\} = \pi_{2a}^F(s_2^{F*})$ in case 2, or $\max\{\pi_1^F(., s_2^*)\} = \pi_{1b}^F(s_1^{F*})$ and $\max\{\pi_2^F(s_1^*, .)\} = \pi_{2b}^F(s_2^{F*})$ in case 3. Combining 1 and 2 and by symmetry, we find that an asymmetric equilibrium can exist between two firms (suppose that Firm 1 offers the lower service level) only if $\sigma_1 < 2b$ and $\sigma_2 < \frac{2bs_1^{F*}}{b - 3s_1^{F*}}$. The payoffs of both firms are well behaved in that they are *continuous but for upward jumps* as defined by Milgrom and Roberts (1994); once again pointing towards the existence of pure-strategy Nash equilibria. In order to identify these MVI combinations for which there exists an equilibrium, we find bounds on the firm parameters (MVIs σ_1 and σ_2) that satisfy the above requirements, i.e. for which two types of firms will the market result in an equilibrium outcome. While algebraically tedious (hence the proof is relegated to the appendix), our approach provides lucid solutions to firm and regulator problems, and allows us to derive managerially relevant insights on portal competition under privacy.

Lemma 1: *When both portals offer only a fixed-service toolbar, there exists an asymmetric equilibrium given by* $\left(s_1^{F*}, s_2^{F*}\right) = \left(\frac{b\sigma_1\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}, \frac{2b^2\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}\right)$ *when the competition is characterized by one portal with low MVI* $\sigma_1 < \frac{2b}{1+\sqrt{2}}$ *and other with a relatively higher MVI* $\sigma_2 \geq \frac{8b^2\sigma_1}{4b^2 - 4b\sigma_1 - \sigma_1^2}$.

Lemma 1 tells us that if firms are sufficiently differentiated by their marginal values for information and if one portal has a low MVI, then the two firms will share the marketplace in such a way that the low MVI firm caters to consumers with low p4p ratios and the high MVI firm caters to those with high p4p ratios. Note that when both firms offer fixed services, the NFD nature of the good does not come into play, i.e., it does not matter what the ideal points are, consumers will select a service-level as along as their individual rationality (IR) constraints are satisfied, and their choice of firm will depend on the individual's incentive compatibility (IC) constraint. We also know that for a given service level, consumer utilities are increasing in the p4p ratio, i.e., $u_1(s) > u_2(s)$ if $\left(\frac{p}{r}\right)_1 > \left(\frac{p}{r}\right)_2$. Hence along the lines of strictly vertically segmented markets, we have an equilibrium where one firm serves the low types and the other serves the high types. (Moorthy 1988). The condition on the separation of MVI's essentially ensures that the firm with low MVI will not attempt to undercut the higher MVI competitor due to the trade off between his costs and marginal value for information.

Interestingly, note that while the services offered by both portals are increasing in σ_2 of the high MVI portal, the services offered by high MVI portal (s_2) is decreasing in σ_1 while the low MVI's services (s_1) continue to increase in his own MVI. The intuition behind this is that if the MVIs are sufficiently far apart, the portals will make themselves attractive to very distinct segments and as the lower MVI approaches $2b$, this firm will begin to offer services that are now attractive to some consumers (who were using more than their optimal levels) of the high MVI portal. Hence for the large MVI portal, the cost of offering high number of services is not offset by the demand captured and will therefore lower his service level. Further, we know that the number of consumers who are not served $\left(s_c^0 < s_1^{F*}\right)$ increases in MVI, while on the other hand some consumers (with high p4p ratio) might receive services closer to their optima. This portends interesting consumer (and hence social) welfare implications that we shall explore later. In fact, since $\lim_{\sigma_1 \to 2b} s_1^{F*} = s_2^{F*}$, we not only know that the threshold is important in maintaining the asymmetric equilibrium but also that there is potentially a symmetric equilibrium if the MVIs of both firms are sufficiently high.

Lemma 2: *When both portals offer only a fixed-services toolbar, then there exists a symmetric equilibrium given by* $s_F^* = \left(s_1^{F*}, s_2^{F*}\right) = \left(\frac{b}{3}, \frac{b}{3}\right)$ *when competition is characterized by both firms having high MVIs* $(\{\sigma_1, \sigma_2\} \geq 2b)$. *For all other portal characterizations (e.g., both portals with low MVI* $(\{\sigma_1, \sigma_2\} < 2b)$*, there exists no symmetric equilibrium even for identical MVIs.*

Lemma 2 suggests that when both portals have high MVI and both offer a fixed-services take-it or leave-it offer, the only feasible equilibrium is characterized by portals offering the same level of services and sharing the market equally. Note that not only is the equilibrium service level purely a function of consumers' p4p distribution, but also portals need not have identical MVIs for symmetric equilibrium to exist; it is only required that both portals have MVIs weakly higher than a threshold $(2b)$. This suggests that even if two portals had the ability to offer a greater number of services, doing so would make a portal attractive to consumers to the right $\left(\text{consumers with } s_c^* \in \left[s, \frac{b}{2}\right]\right)$ while those on the left $\left(\text{with } s_c^* \in \left[\frac{b}{3}, s\right)\right)$ might begin to prefer the competitor. Essentially, above the equilibrium service level, gain from high p4p consumers' usage of services does not outweigh loss from offering services above this level. This implies that with a fixed-services approach, a portion of the market will always be left un-covered. In particular, a third of the market will not be served as consumers with break-even services below the equilibrium service level $\left(s_c^0 < \frac{b}{3}\right)$ will not use any personalization services.

The implication of this result is that even if the marginal cost of serving an additional consumer is zero, the competitive dynamics of a fixed-services approach will lead portals to maximize profits by not serving the segment of consumers with minimal value for personalization and/or high privacy concerns. At the same time some consumers $\left(\frac{b}{3} < s_c^* \leq \frac{b}{2}\right)$ are left wanting for more services as the equilibrium service level will not fully satisfy this segment. An important reason as to why firms need to possess sufficiently high MVIs for the symmetric equilibrium to exist is that when one firm is below the threshold, there is always tendency for the firms to serve different portions of the market as in Lemma 1. On the other hand, when both are below the threshold, symmetric equilibrium is not feasible either because sharing the market is never an optimal strategy. The simple intuition is that since consumers are indifferent between the services offered by the two portals as long as they offer the same level of services, both portals incur the full infrastructure costs while only getting half the market and firms could always increase this market size by offering slightly more or fewer number of services. Another important implication is one that hints at reducing consumer privacy concerns. We can see that profits of both firms are increasing in consumers' p4p ratios and prior research (Chellappa and Sin 2005) suggests that engendering trust in a personalization context may reduce privacy concerns. While it is beyond the scope of this paper, one could observe that even if service offerings are indistinguishable, portals may better their profits by differentiating themselves on the basis of consumer trust.

3.2 Market Outcomes When Both Portals Offer Variable Services

We now consider the more common scenario where portals offer a toolbar of certain length, but allow consumers to use only a subset of services by turning off information acquisition for some services thus forgoing personalization benefit from these services as well. The NFD property of the good plays an important role here in that with the option of choosing their own service levels, consumers will choose only their optimal service level s_c^* if available. Since consumers will be indifferent between the services offered by the two portals, both portals will share the consumer segment with $s_c^* \leq \min\{s_1, s_2\}$. The rest $\left(s_c^* > \min\{s_1, s_2\}\right)$ will use services from the portal offering a higher service level because they can no longer be satisfied by the other portal. However, note that this segment of consumers can only use their ideal level of services up to the level offered by the firm with more services; beyond which they can only use the exact amount that is offered. Thus, we can formally write Firm 1's profit functions as

$$\pi_1^V = \begin{cases} \pi_{1a}^V = \frac{1}{2}\sigma_1 \int_0^{s_1} s_c^* U(s_c^*)\, d(s_c^*) - s_1^2 & \text{if } (s_1 < s_2) \\ \pi_{1b}^V = \frac{1}{2}\sigma_1 \left[\int_0^{s_1} s_c^* U(s_c^*)\, d(s_c^*) + s_1 \int_{s_1}^{\frac{b}{2}} U(s_c^*)\, d(s_c^*)\right] - s_1^2 & \text{if } (s_1 = s_2) \\ \pi_{1c}^V = \frac{1}{2}\sigma_1 \int_0^{s_2} s_c^* U(s_c^*)\, d(s_c^*) + & \\ \sigma_1 \left[\int_{s_2}^{s_1} s_c^* U(s_c^*)\, d(s_c^*) + s_1 \int_{s_1}^{\frac{b}{2}} U(s_c^*)\, d(s_c^*)\right] - s_1^2 & \text{if } (s_1 > s_2) \end{cases}$$

We can observe that for some firm parameters, offering a service level lower than that of the competitor is a strictly *dominated* strategy; when $\sigma_1 \leq 2b$, π_{1a}^V is negative regardless of the service level offered by Firm 2. The intuitive reason is that when both firms offer variable services, the firm offering lower service level incurs the full cost of offering the service while being assured of only half the market corresponding to that service level. On the other hand, if $\sigma_1 > 2b$, π_{1a}^V is still increasing as s_1 approaches s_2, implying that this firm will prefer to offer the same or higher number of services as his competitor. Extending this logic to Firm 2 and by symmetry we can easily preclude the possibility of an asymmetric equilibrium when variable services define the market. Therefore if the Nash equilibrium pair is given by s_1^{V*}, s_2^{V*}, then from Firm 1's perspective and for any Firm 2 there *might* be

1. A symmetric equilibrium where he offers the same services as Firm 2, given by $s_1^{V*}, s_2^{V*}\left(s_1^{V*} = s_2^{V*}\right) = \left\{s_2^{V*}, s_2^{V*}\right\}$ for any MVI of Firm 1
2. No asymmetric equilibrium.

In order for the service-pair $\left\{s_1^{V*}, s_2^{V*}\right\}$ to be an equilibrium candidate, we need to have $\max\left\{\pi_1^V\left(., s_2^*\right)\right\} = \pi_{1b}^V\left(s_1^{V*}\right)$ and $\max\left\{\pi_2^V\left(s_1^*, .\right)\right\} = \pi_{2b}^V\left(s_2^{V*}\right)$. Similar to the previous cases, we derive boundaries on the firm parameters (σ_1, σ_2) so as to explore for the possibility for any equilibrium strategy.

Lemma 3: *When both portals allow consumers to self-select their respective service levels, only a symmetric equilibrium is possible; which exists only when the competition is characterized by two high MVI portals* $(\{\sigma_1, \sigma_2\} > 2b)$. *The equilibrium number of services offered by each firm will be the full set, given by* $s_V^* = \left(s_1^{V*}, s_2^{V*}\right) = \left(\frac{b}{2}, \frac{b}{2}\right)$. *For all other portal types there is no market equilibrium even if their MVIs are identical.*

This situation is unique to our model that is characterized by NFD property of the services, and the zero marginal and versioning costs of offering variable services. The intuition behind Lemma 3 is as follows: since consumers are indifferent between the two portals and are free to choose their individual desired levels of personalized services, if two portals offer different service levels, then the portal offering the higher service level would get half of market of its competitor and will further capture the entire segment of consumers whose personalization needs are higher than the competitor's offering (i.e. consumers with $s_c^* \in [\min\{s_1, s_2\}, \max\{s_1, s_2\}]$). While offering more services than the competitor appears preferable, because no consumer has s_c^* greater than $\frac{b}{2}$, no portal would offer services higher than this level. Hence, if the MVIs are high enough for portals to offset the cost of offering such a high level of personalization, both portals would offer the maximum level of services desired by the consumers in equilibrium. Thus the equilibrium service level is independent of the portals' own MVIs (as long as they are above the threshold) and all consumers enjoy their ideal level of personalization services.

It is salient to note the difference between the full lengths of the toolbar (the maximum number of personalization services offered) in the two symmetric equilibria described in Lemmas 2 and 3, given by $\frac{b}{3}$ and $\frac{b}{2}$ respectively. While the market is not covered under the fixed-services case, not only are all consumers being served but consumer welfare is also *maximized* in the latter case. While a monopolist would be indifferent between offering a fixed toolbar strategy or one that allows consumers to choose their preferred level, in a competitive model it is not clear yet whether firms with high MVIs will necessarily prefer one over the other. Intuitively, it might appear that firms would prefer to set the service levels and consumers use the prescribed level, consistent with price setting behavior in most markets. However, in our context of zero marginal and versioning costs, the results might yet be surprising as even if variable services is consumer-welfare maximizing, the market is fully covered thus holding out the distinct possibility of being better for the firm than the fixed-services strategy when a third of the market is always left un-served. Before we discuss the social welfare implications of fixed and variable strategies, we shall first consider a hybrid case where one firm chooses to offer a variable-services contract while the other opts for a fixed-services one.

3.3 Market Outcome When One Portal Pursues Fixed While the Other Pursues Variable Services

Without loss of generality, assume Firm 2 to be the one that offers a toolbar of fixed length, while Firm 1 allows consumers to choose services in a variable fashion. First consider the case when both firms offer different levels of services $(s_1 \neq s_2)$. If Portal 1 offers fewer number of services than 2 $(s_1 < s_2)$, then all consumers with surplus maximizing number of services lower than that offered by Firm 1 $\left(s_c^* \leq s_1\right)$ would choose Firm 1 because they can freely choose their ideal level to consume. The remaining consumers would choose Firm 1 if their utility from using s_1 is greater than that from s_2, i.e. $u_c(s_1) > u_c(s_2)$. We can see that consumers whose p4p ratio $\frac{p}{r} \in [2s_1, s_1 + s_2)$ will still use Firm 1's services. However, if Firm 1 offers more services than 2 $(s_1 > s_2)$, all consumers will choose Firm 1 and use their individual utility-maximizing number of services. If both firms offer the same level of services $(s_1 = s_2)$, Firm 1 would capture all consumers whose $s_c^* \leq s_1$ and half the market of all remaining consumers. We can hence construct profit functions of the respective firms according in the same fashion as we did in the previous cases (we shall omit the details here due to space limitation).

Lemma 4: *In a duopoly where one portal pursues a fixed-services strategy while the other does not, there is no symmetric equilibrium. An asymmetric equilibrium exists if the MVI of the portal allowing variable services is low* $\left(\sigma_1 < \frac{2b}{1+\sqrt{2}}\right)$ *and that of the one pursuing fixed-services strategy is sufficiently higher* $\left(\sigma_2 \geq \frac{8b^2\sigma_1}{4b^2 - 4b\sigma_1 - \sigma_1^2}\right)$. *The equilibrium pair is given by*

$$\left(s_1^{\tilde{V}*}, s_2^{\tilde{F}*}\right) = \left(\frac{b\sigma_1\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}, \frac{2b^2\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}\right).$$

It is quite apparent that it cannot be optimal for a portal to engage in a fixed-services strategy and offer the same or fewer number of services than its competitor who allows consumers to choose their preferred levels. Also note that the service offerings are the same as in Lemma 1 (asymmetric equilibrium when both portals offer fixed services), although the difference of MVIs between the two firms needs to be larger. This differentiation is driven by both bounds, i.e., the small MVI firm is smaller than his counterpart in Lemma 1 and the large MVI firm has to be larger at the same time. Intuitively, we can see that the small MVI firm, by offering variable services, is essentially serving those consumers who would have been left un-served when both firms offered fixed services (Lemma 1), i.e., those with very low p4p ratios $\left(s_c^0 < \frac{b\sigma_1\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}\right)$. Further, unlike in Lemma 1, the market will be fully covered in this situation as the worst any consumer in this market can do is to use $s_1^{\tilde{V}*}$.

An important finding of our analyses is that in equilibrium, whenever at least one portal offers variable services, the market will always be fully covered and the consumer surplus will always be higher. The simple intuition behind this is that whenever one firm allows consumers to choose their desired service levels, every consumer can find a service level that correspond to a non-zero utility; while low types will pick up some service level lower than that offered by the variable-services firm, the high types will choose between this firm and the competitor who offers a higher service level. Thus from a consumer surplus point of view as well even if one firm offers variable-services, consumers are always better off. Further, note that when the MVI of the fixed-services firm increases, *both* firms would find it optimal to increase their service levels. While the increase in the fixed-service level may or may not lead to increased consumer surplus, the increase in the smaller MVI firm's offering will result in a greater portion of consumers in the market being satisfied at their preferred level.

3.4 Welfare Analysis

Having derived the equilibrium solutions under different combinations of services-strategy, we shall now analyze their implications to consumer and social welfare. From our earlier discussions, it is quite evident that when one (both) firms pursue a variable services strategy, some (all) consumers enjoy their surplus maximizing level of services.

Lemma 5: *In the duopoly where there is at least one low MVI firm* $(< 2b)$ *and the higher MVI firm offers fixed-services, the market is fully covered and consumer-welfare is higher when the low MVI firm offers variable services than when both offer fixed-services. In the market characterized by two firms with sufficiently high MVIs* $(\sigma_1, \sigma_2 > 2b)$, *we observe the following:*

i. *Consumer surplus is always maximized when both firms adopt a variable-services strategy in equilibrium.*

ii. *Firm's equilibrium profits from adopting variable-services strategy is higher than their corresponding profits from engaging in fixed-services, when their respective MVIs are very high* $\sigma_1, \sigma_2 > 10b$ *and the social-welfare is the highest in this case.*

iii. *Even if firm MVIs are lower than the threshold in (ii), equilibrium social welfare in variable-services strategy is higher than that under fixed-services strategy under a lowered limit* ($\sigma_1 + \sigma_2 > 20b - 6$)

Parts of Lemma 5 are quite intuitive in that due to the NFD property of the good, when variable services are being offered, consumers will pick up their respective optimal service levels available and thus raising consumer surplus. However, interesting observation of Lemma 5 is that while variable-servic are obviously good for the consumers, in some cases, they a also superior to fixed-services offerings for the firms as well. T economic intuition behind this finding is that for high MVI firm the combined loss from not serving a third of the mark (consumers with low p4p ratio $s_c^0 < \frac{b}{3}$) and not catering to son convenience-seekers at their preferred level (those wi $\frac{b}{3} < s_c^* \le \frac{b}{2}$) is higher than the costs of increasing their servi level from $\frac{b}{3}$ to $\frac{b}{2}$. Contributing to this observation is the fa that firms suffer *no marginal or versioning* costs in catering consumers who choose a service level lower than the full offerin Closer to the threshold of $2b$, fixed-services is better th variable-services strategy though both profits are increasing in t firms' MVI. However, profits for firms in the variable case a increasing at a faster rate with MVI as compared to the rate increase in the fixed case $\left(\frac{\partial \pi^{V*}}{\partial \sigma} > \frac{\partial \pi^{F*}}{\partial \sigma}\right)$. This aspect combin with the fact that consumer surplus is higher in the variable case ensures that the social welfare with variable services is higher than that of the fixed-services even before firms themselves find it optimal to offer variable-services (hence the $\sigma_1 + \sigma_2 > 20b - 6$ condition rather than $\sigma_1 + \sigma_2 > 20b$).

In this paper, we have analyzed equilibrium strategies under different cases of services-strategy adoption. From Figure 1, we can see that there is a small region describing competitive markets where no pure-strategy equilibrium exists. While this generally suggests that firms might continue to undercut each other by offering services that are perhaps not optimal, there is also a distinct possibility of mixed-strategy equilibria in this space. This would essentially suggest that firms of these types will randomize their services strategies. One main purpose of this work is to illustrate the problem from a regulator's point of view as to what the consumer and social welfare implications might be under different cases. However, one could also view our analyses as the subgame equilibrium results of a two-stage game where firms first simultaneously choose their strategy of offering (fixed vs. variable-services), and in a second stage choose their service levels. In this case our equilibrium results would be the candidates for a subgame perfect Nash equilibrium (SPNE) of the two-stage game. In order to study the equilibrium outcome of such a game, we would be comparing the profits identified in each of the Lemmas. In fact, we can see that in general when a firm faces a competitor whose profits are increasing in services, then offering variable services weakly dominates offering fixed services; because offering fixed services when a competitor might offer variable will result in the firm accruing negative profits. Similarly, we could extend the model to a 3-stage game, where in the first stage the firms strategically determine their marginal values for information (MVIs) by investing in developing their own advertising networks and incurring some costs. Clearly the results of such a game would depend on the relative costs incurred by the two firms and is beyond the scope of this paper.

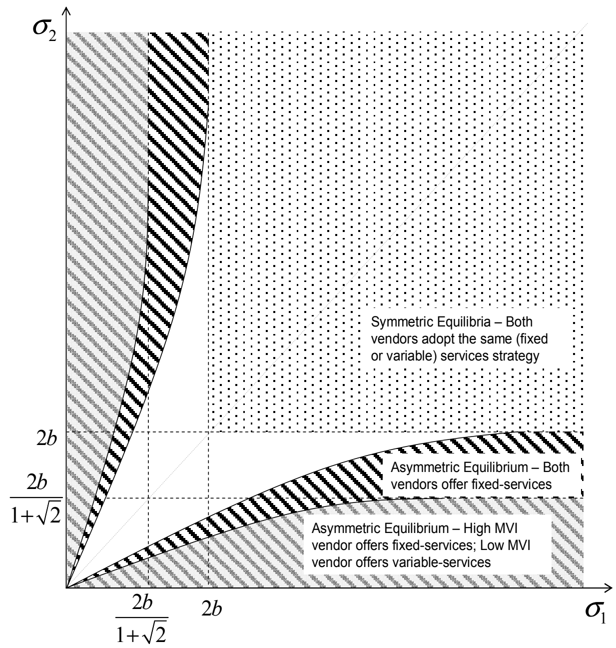

Figure 1. Equilibrium regions in the duopoly.

4. POLICY IMPLICATIONS AND DISCUSSION

An important motivation for our problem is the emergence of new browser-embedded technologies such as toolbars that provide firms with greater control over how information about consumers' online usage is acquired. The fixed-services strategy – the option to acquire a fixed-amount of information and deliver a given set of personalized services – was hitherto non-existent as early forms of personalization was largely restricted to user controlled Web-based static mechanisms. For example, personalization through a Web interface relies largely on server logs and cookies (Murthi and Sarkar 2003) and it is difficult for a firm to require consumers to use all services offered. Due to the static nature of the Web's Hyper Text Transfer Protocol (HTTP), the most control that firms enjoyed was that they could "expire" accounts that did not use enough services or share adequate information. It is in fact the fixed-services contract that a user agrees to, often with little or no control subsequently, that has gotten the attention of the media and privacy groups that compare these toolbars to spyware technologies, e.g., the recent campaign against Ask

Jeeves (Stone 2005). It is indeed this potentially detrimental level of control over how much users share and what they get the main subject of ongoing FTC investigations into the legitimate and illegitimate uses of toolbar-like technologies (FTC 2004).

While many spurious firms are employing toolbars giving rise to their "Spyware" reputation, due to its non-intrusive nature, numerous legitimate online firms are employing it for personalizing services to their users. Currently, large portals like Yahoo! and MSN offer all of their personalization services (more than those available through their Web-based technologies) through browser-embedded toolbars. Their strategy so far has been to allow consumers to select a subset of their toolbar services. For example, Google provides a toolbar wherein one could personalize search, mail, and a variety of other services including a feature called PageRank that is considered to be highly intrusive by many. However, Google provides users with the option of using only a subset of its toolbar-based personalization, allowing users to turn-off the PageRank option and thus not collecting the associated information. This is in contrast to strategies of those in the retail space such as Amazon with its Alexa and A9.com toolbars, where Amazon does not allow consumers to choose a subset of services to personalize. Once a user downloads and embeds the A9.com toolbar, a variety of information including the Web-sites visited, products searched for, email addresses used in fill-in forms, etc., is automatically acquired and the user is then provided with a personalized list of sites and products during next usage; although currently the toolbar is focused only on products carried by its parent company, Amazon.com. The user has no control in that he cannot specify that the A9 toolbar should collect and report information (and hence personalize) only on certain services but not others.

4.1 Policy Implications

Our results categorically suggest that the non-price nature of online personalization market, combined with the NFD property of services, creates a situation where the availability of variable services is always superior from a consumer surplus perspective. This is in contrast to pricing strategies for goods with free disposal, where a monopolist typically can extract more consumer surplus by offering variable rather than fixed contracts (Sundararajan 2004). In our model, a monopolist is indifferent between the two strategies but in a competitive situation many equilibrium possibilities exist; each with its own consumer and social welfare implications. First of all, we note that in the case of both firms having high MVIs, a symmetric equilibrium where firms offer variable services is superior not only from the consumer-surplus perspective but also for the producer surplus and hence the overall social welfare of the market. It is evident that the adoption of fixed-strategies in equilibrium is largely a function of whether one or both firms have smaller marginal value for information.

An important policy implication of these findings is that perhaps the regulator need not outright ban the use of technologies such as toolbars, but rather ensure the participatory aspect of the consumer-firm interaction to be in favor of the consumers. Interestingly, our results suggest that the regulator needs to be more concerned with the many small firms who survive on the limited re-sale value for information than with large firms with sophisticated uses for consumer data. There is also a clear indication towards encouraging both competition and the allowance of firms to mine preference/usage information as long as consumers are made fully aware of their privacy implications. Thus an important recommendation of our work will be for a regulator like the FTC to not engage in the legislation of what technologies can or cannot be used, but rather focus on the explication of the impacts of these technologies through education and more importantly, monitor and enforce any agreements between firms and consumers.

One other suggestion might be to allow for ongoing consolidations in the portal space where many portals are beginning to merge, thus reducing the number of smaller independent portals to a few large ones. For example, Yahoo! now owns Inktomi, Overture, and Altavista; Lycos has acquired or merged with Tripod, Angelfire, Matchmaker and Wired; InfoSpace now includes Dogpile, WebCrawler, MetaCrawler and WebFetch. This is perhaps one of those unique markets where an oligopoly of a few large players might be beneficial to the consumers. Through variable-services offerings large firms also end up serving those consumers in the fringe of the market (i.e., highly privacy-sensitive consumers).

4.2 Summary

From a modeling point of view, our research adds to the literature on competition in NFD goods and services markets; and from a theoretical perspective, the competition is characterized by discontinuous payoffs that generally suggest existence of equilibrium only in mixed-strategies (Dasgupta and Maskin 1986). However, we find that our payoffs can also be classified as *continuous but for upward jumps* (Milgrom and Roberts 1994), and the aggregator function (sum of payoffs across the strategy space) is both Diagonally Transfer Continuous and Diagonally Transfer Quasi-concave (Baye et al. 1993). This allows us to explore more meaningful pure-strategy equilibria.

We discuss two firm strategies, one where they offer a fixed set of services to consumers and in the other where variable services are offered. When fixed-services are offered and consumers are distributed in their effective marginal value for services, the market is characterized by competition reminiscent of vertically segmented markets. Our results show the existence of a segmented market along the lines of Moorthy (1988), where a firm endowed with a lower marginal value for information serves the low types while the higher MVI firm serves the high types. However, unlike segmented markets for goods with free disposal, we also observe a symmetric equilibrium where both firms offer the same level of services and share the market equally. The market is not covered in either case.

The NFD aspect of the good combined with the zero-marginal and zero-versioning costs have a pronounced effect when the market is characterized by variable-services offering. Unlike in the fixed-services case where non-zero utility was the main participation criteria, in the variable-services case consumers select services based on how far they are from their ideal-points (the surplus-maximizing level) and many consumers may be satisfied at their desired levels. The closest physical world examples can be found in models of franchise competition where fast-food franchises and car dealerships can locate themselves at multiple points on a linear market (Hadfield 1991; Iyer 1998). Our results show that such a market is only characterized by symmetric, consumer-surplus maximizing equilibria in a duopoly of high MVI firms. From a modeling perspective, this draws comparisons with outside location game similar to that in Gabszewicz and Thisse (1992) where firms place themselves on the edge of a linear market and maximize welfare.

From a managerial perspective, since firms' profits are increasing in consumers' p4p ratio, our results suggest that firms should employ significant trust building and other reassuring services that are known to help allay privacy concerns and therefore increase the p4p ratios. Since firms with large MVIs will have a strong incentive to move towards variable-services offering, it is evident that smaller independent portals that solely depend on external agencies like DoubleClick for generating value from information will find it hard to continue sustaining in this market. Perhaps these smaller portals will distinguish themselves by going the niche services route or will be absorbed into some larger portals. It is also interesting to note that while in the highly competitive marketplace portals offer variable toolbar-sizes, Amazon is currently persisting with fixed-services approach. This could perhaps be attributed to its near monopoly status in the area of retail personalization, although our model would suggest that with increasing number of firms occupying this space, Amazon will eventually allow consumers the option to choose a subset of its A9.com toolbar services.

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