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Abstract

The revenue model of online portals is based on access to consumers and their preference information through offerings of "free" personalized services. Extant research has characterized consumer behavior in this context by a personalization for privacy (p4p) ratio, which represents consumer's tradeoff between value for personalized services and nonmonetary privacy costs incurred in sharing their preference information. In determining the optimal level of services, two factors affect a portal's personalization strategy: its marginal value for preference information (MVI) and its ability to enforce consumers' usage of services. Counter to intuition, our results show that a monopolist is indifferent to enforcement abilities, even if social welfare is strictly higher in the absence of enforcement. Our duopoly model reveals that when portals do not enforce services usage, a symmetric equilibrium exists if and only if the MVI of both portals is high and no equilibrium is found otherwise. On the other hand, when portals enforce services usage there are two possible outcomes: (1) an asymmetric equilibrium exists if one portal has high marginal value for information and the other has sufficiently lesser MVI, and (2) a symmetric equilibrium exists if and only if both portals have high MVI. We discuss our results in light of portals' usage enforcement and from the perspective of a regulator who is interested in social welfare in the presence of privacy concerns.

Keywords: Personalization, privacy, equilibrium, welfare

Introduction

The operational basis for many Web-based portals is unique in that they offer "free" personalized services to online consumers while largely relying on the ability to sell browsing profiles to advertisers and targeted marketers (Dewan et al. 1999). On the other hand, some large portals such as AOL not only resell information but also operate their own advertising networks. Yahoo!, mainly a carrier of DoubleClick's DART-based advertisements, recently acquired Overture to run its own contextual advertising network. The revenue model of these portals hinges on the ability to acquire and resell (or use on their own) consumers' preference and usage information while incurring technology, trust-building, and liability costs of collecting, processing, and storing customer information. Consumer behavioral research suggests that although apparently costless from the monetary point of view, individuals incur privacy costs when sharing information about themselves and their preferences during personalization (Volokh 2000). In this regard, an important research question that has largely been unanswered so far is how online portals should determine their optimal service levels in the presence of consumer concerns of privacy. This problem is further complicated by the fact that ubiquitous availability of sophisticated Web and data mining technologies has allowed all types of portals to offer virtually indistinguishable personalization services.

Another interesting facet of online portal competition is the ability (or inability) of portals to enforce services usage. If a consumer is *forced* to provide more than her optimal amount of information, she will provide her true preferences up to her optimal level of services and then *may* provide incorrect information for the rest of the services. For example, when using the free Real Audio service, a consumer who values the personalized radio service will voluntarily indicate her preferences for various music genres, but if Real Audio makes it compulsory for her to provide other personal information (often an asterisk next to fields) such as an e-mail address, the consumer might simply provide a fictitious one. However, in some contexts there may be technologies that allow portals to enforce service usage agreement. For example, Yahoo! and Hotmail's e-mail services become unavailable if a consumer turns the "cookies" feature off. Similarly, in the Real Audio case, the portal can provide a password (to access the music genres) that is sent only to the user's e-mail address; in which case the consumer is compelled to provide her actual e-mail address. Since the demand for services largely depends on the portal's ability to ensure consumer's usage, two distinct cases that represent the *presence* and *absence of enforcement abilities* need to be studied respectively. Potentially, allowing (or disallowing) enforcement through legal and technological means can have significant impacts on social welfare and hence is of great interest to regulators such as the Federal Trade Commission.

In order to study both market outcomes and the regulator's problem, we first study a monopolistic market and contrast the results under the presence and absence of enforcement. We then construct a duopolistic model where portals are differentiated on the basis of their marginal value for information (MVI) that is representative of portals that only resell consumer information (low MVI) and those that also run their own advertising networks (high MVI). Our analytical approach is built upon behavioral work which suggests that consumers are more likely to accept loss of privacy if it accompanies some benefit (Laufer and Wolfe 1977) and the consumer's decision to share information is based on some "privacy calculus" (Culnan and Bies 2003). In the context of personalization, this privacy calculus has been abstracted through the consumers' personalization for privacy (p4p) tradeoff that is a ratio of their marginal values for personalization and their privacy costs coefficient (Chellappa and Shivendu 2003). We analyze a market where consumers are distributed on their p4p ratios and compare the equilibrium outcomes under the presence and absence of enforcement by portals with different MVI.

The Model

We consider two agents: online portals and consumers of personalization services. Portals' provision of personalization is dependent upon two factors: (1) the existing state of data mining and other technologies available and (2) the amount of preference information that consumers provide. Technologies determine how portals can use consumer information to tailor services to individual consumer's tastes, for example, tools that interface with consumers over the Web and house personalization engines that are based on various data mining techniques (Raghu et al. 2001; Winer 2001). Thus for a given amount of consumer information, the current level of technology determines how many personalized services can be created.

This information-services mapping is given by a linear function $i = g.s.$,, where i is the customer's preference information (ordered to be increasingly personal), s is the personalization services, and g represents the current state of personalization technology. An advanced personalization technology ($g < 1$) would imply that multiple units of personalization services can be created even for a single unit of information. It is generally agreed that personalization itself is somewhat still in its infancy even if information acquisition technologies have made significant advances (Chen and Hitt 2002). Hence throughout this paper, we assume a simple personalization technology ($g = 1$) where only a single unit of service can be generated from each unit of information (i.e., $i = s$).

Mapping the Consumers' Utility and the Portals' Profit Functions

The primary benefit to consumers from using personalized services is the convenience value personalization provides against the opportunity cost that would be incurred in the absence of such services. While price premium is generally absent in the online context, consumers incur privacy costs in sharing the information needed for personalization and their willingness to share information is a function of their perceived benefits of disclosure balanced with its risks (Derlega et al. 1993). Consumers vary both in their value for personalization and concerns for privacy (Chellappa and Sin 2004), and a consumer c's utility from using personalization services can be written as

$$u_c = p_c s - r_c i^2 \qquad (1)$$

where p is the marginal value for personalization and r is her privacy cost coefficient. Note that u_c is a non-monotonic concave function in s where the inverted U-shape implies that consumers have an ideal service level and more services is not necessarily better.

Online portals' revenues are primarily based on advertising value of the information. Portals such as citysearch.com and about.com offer free personalized information and services to consumers and use the DART technology to channel information to the advertiser DoubleClick. On the other hand, AOL and Yahoo! (which recently purchased Overture's contextual advertising technology) have sophisticated advertising capabilities of their own that can generate greater value from customers' preference information than merely reselling or channeling information. Depending upon their ability to sell or use information, portals may vary in their marginal value for information (MVI) even if citysearch.com can offer a subset of Yahoo!'s services. Hence we construct a portal's profit function as

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

where σ_j is the marginal value for information of a portal *j* and *A*(*i*) is the aggregate information acquired from the usage of *s* personalization services. Broadly there are three types of costs involved in providing personalization services: technology infrastructure costs, trust building costs, and information protection or liability costs. While infrastructure costs mainly stem from employing personalization tools and integrating with back-end manufacturing systems (Kwak 2001), trust building and liability costs arise from forming alliances with trusted third-parties (e.g., TRUSTe, WebCPA, Verisign), implementing security mechanisms and complying with the FTC requirements (FTC 2000) as well as special legislative requirements such as the Children's Online Privacy Protection Act (COPPA) and the Health Insurance Portability and Accountability Act (HIPPA) (Anonymous 2001; Bloom et al. 1994; Scott 1999). In this paper, we assume that portals incur similar costs in offering services and only vary in their value for information, hence dropping the portal-specific cost coefficient discussed elsewhere (Chellappa and Shivendu 2003).

Role of Services Usage Enforcement

Consumer behavior can be largely abstracted by two service levels: services s_c^0 that represent the maximum number of services a consumer would use and her individual ideal service level s_c^*. While the former is the break-even or zero utility service level $u_c\left(s_c^0\right) = 0$, the latter is the solution to the utility maximization problem $u_c\left(s_c^*\right) = \max_s ps - ri^2$. Substituting for the current state of personalization technology (*g* = 1), we can simplify and rewrite equation (1) as

$$u_c\left(s\right) = p_c s - r_c s^2 \tag{3}$$

This gives $s_c^0 = \dfrac{p_c}{r_c}$ and $s_c^* = \dfrac{p_c}{2r_c}$. The ratio $\dfrac{p}{r}$ is known as the consumers' personalization for privacy (p4p) ratio and is a critical parameter for analysis of consumer behavior as it determines both her indifference and optimal service levels. If it were up to the consumer, she would clearly prefer to use her optimal service level s_c^* as any higher service level reduces utility. But if it were feasible, a portal might prefer the consumer use a specific service level and the consumer would do so as long it warrants non-negative utility, i.e., any service level $s \in \left(0, s_c^0\right]$. Hence we can envision two scenarios, one where portals can force consumers to use the service levels they set and the other when they cannot do so.

Whether technological and legal tools can be employed to force a consumer to share information beyond their optimal level can also be viewed as a regulator's problem as the decision is likely to influence social welfare. Recently, privacy groups have been up in arms against Google's Gmail for its proposal to scan e-mail to deliver personalized advertisements and the FTC has been asked to look into this issue (Van Grinsven and Warner 2004). Potentially, a regulator such as the FTC can approve or prohibit the use of intrusive tools and means that help portals enforce a contracted level of services and hence we study market outcomes under both conditions.

Monopolist and Usage Enforcement

We define a market where consumers differ in their personalization and privacy perceptions, which is captured by variations in their p4p ratio, with privacy-sensitive consumers (privacy seekers) having relatively low p4p ratios while higher p4p ratios represent their less privacy-sensitive counterparts (convenience seekers). We consider the p4p ratio to be uniformly distributed in a unit market, i.e., $\frac{p}{r} \sim U[0,b]$. This enables us to represent the break-even and optimal service levels to be given by the distributions $s_c^0 \sim U[0,b]$ and $s_c^* \sim U[0,b]$ respectively. When a portal can enforce consumers' usage of personalization services, all consumers with s_c^0 above s will use the services and the aggregate information that the portal will acquire in terms of the services consumed can be written as $A_m^F = \int_s^b sf\left(s_c^0\right)ds_c^0$, with the corresponding profit function

$$\pi_m^F = \sigma\left(\int_s^b sf\left(s_c^0\right)ds_c^0\right) - s^2 \tag{4}$$

A more general depiction of online personalization is the absence of enforcement abilities as it is often difficult for portals to require consumers to use a certain level of service. When the portal cannot enforce usage, consumers will only use their optimal service level s_c^* as long it is available (consumers with $s_c^* \leq s$) and will simply use the given service level otherwise. Thus the aggregate information the portal will acquire in terms of the services consumed is $A_m^{NF} = \int_o^s s_c^* f\left(s_c^*\right)ds_c^* + \int_s^{\frac{b}{2}} sf\left(s_c^*\right)ds_c^*$ and the profit function can be represented as

$$\pi_m^{NF} = \sigma\left(\int_o^s s_c^* f\left(s_c^*\right)ds_c^* + \int_s^{\frac{b}{2}} sf\left(s_c^*\right)ds_c^*\right) - s^2 \tag{5}$$

Proposition 1: *A monopolist's optimal service level and profits are the same regardless of usage enforcement (*$s_m^{NF*} = s_m^{F*} = \dfrac{\sigma b}{2(\sigma+b)}$ *and* $\pi_m^{NF*} = \pi_m^{F*} = \dfrac{b\sigma^2}{4(b+\sigma)}$*). However, consumer and social welfare are strictly higher when the portal does not enforce services usage.*

Proposition 1 provides us with some very counterintuitive insights. We find that both the optimal service level and profits are independent of the portal's ability to enforce usage, implying that the monopolist is indifferent between requiring consumers to use a specific set of services and letting the consumers themselves decide on usage. The intuition is that the portal's loss of information (from consumers who have reverted to s_c^* from s_m^{F*}) is compensated by the gain from those who were not able to use the services (consumers whose $s_c^0 < s_m^{F*}$) when usage enforcement was in place. This implies that a social planner or regulator such as the FTC should ideally prohibit portals in monopolistic markets from requiring registration, provision of e-mail address, and other information that consumers themselves may not find optimal to share.

Portal Competition: A Duopoly

Next we study portals' strategies in a competitive market. Consider two portals whose MVIs are 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 three types of competition: competition between portals that have their own advertising and partner networks (high MVI), between two information reselling portals (low MVI), or one of each. We consider a game in which both portals simultaneously choose their respective service levels s_1 and s_2.

Portal Competition When Usage Enforcement Is Allowed and Both Portals Enforce

We first consider the case where the regulator allows portals to use any means to ensure that consumers use a level of service that has been contracted. In this case, consumers will use the level of service that is provided so long as their utilities are non-negative. In the competitive model, 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"). Equation (3) gives the condition for consumers to be deriving a higher utility from using services provided by portal 1:

$$ps_1 - rs_1^2 > ps_2 - rs_2^2 \Rightarrow \frac{p}{r}(s_1 - s_2) > s_1^2 - s_2^2 \tag{6}$$

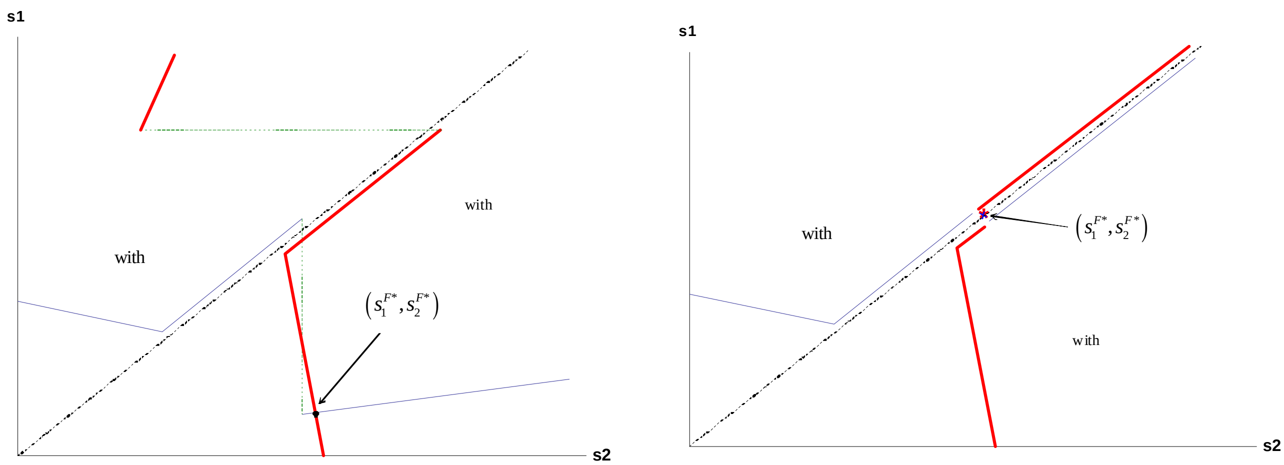
since $s_1 < s_2$, equation (6) implies $\frac{p}{r} < s_1 + s_2$. Notice that consumers with $s_c^0 < s_1$ would not use any services at all, therefore consumers whose break-even service level $s_c^0 \in [s_1, s_1 + s_2)$ would use portal 1's services and the remaining consumers $s_c^0 \in [s_1 + s_2, b]$ 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 ($s_1 = s_2$,, case "b"), then given that consumers are indifferent between the two portals, portal 1 will get half the market of all the consumers who use the services, i.e., half of the consumers whose break-even service level $s_c^0 \in [s_1, b]$. Hence the amount of information that a portal acquires depends upon both the level of service he offers and its magnitude relative to that of the second portal. We can formally write portal 1's profit functions as

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

By symmetry we can construct portal 2's profit function. Now in developing the strategic interactions between portals, we know that portal 1's strategy is a best response to the strategy of portal 2 if it maximizes $\pi_1^F\left(\max\left\{\pi_{1a}^F, \pi_{1b}^F, \pi_{1c}^F\right\}, s_2\right)$ on the whole set of services for the 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 if he is going to be offering a service level that is lesser 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. Note that the profit functions $\left(\pi_{1a}^F, \pi_{1b}^F, \pi_{1c}^F\right)$ are all strictly concave in each of the cases (*a, b, c*) and hence we have the local interior optima as candidates for best response. However, in cases *a* and *c* the profit function does not attain its maximum within the defined regions when $\sigma_1 > 2b$ and $s_2 > \frac{b\sigma_1}{2b + 3\sigma_1}$ respectively. This implies that for some portal parameters and service offerings of the competitor, the profits are still increasing at the limits. Since π_{1a}^F is not defined at its upper limit and π_{1c}^F is not defined at it lower limit, a portal cannot offer services at the limits and will, therefore, offer some level of service very close to s_2 given by some e, $\delta > 0$ respectively. Hence, the best response is discontinuous and can be written as

$$BR_1^F = \begin{cases} \frac{\sigma_1}{2b} s_2 \ \left(\text{for } \sigma_1 < 2b\right) \quad \text{or} \quad s_2 - \varepsilon \ \left(\text{for } \sigma_1 \geq 2b\right) & \text{if } \left(\max\left(\pi_1^F(.,s_2)\right) = \pi_{1a}^F\right) \\ s_2 & \text{if } \left(\max\left(\pi_1^F(.,s_2)\right) = \pi_{1b}^F\right) \\ \frac{(b-s_2)\sigma_1}{2(b+\sigma_1)} \ \left(\text{for } s_2 < \frac{b\sigma_1}{2b+3\sigma_1}\right) \quad \text{or} \quad s_2 + \delta \ \left(\text{for } s_2 \geq \frac{b\sigma_1}{2b+3\sigma_1}\right) & \text{if } \left(\max\left(\pi_1^F(.,s_2)\right) = \pi_{1c}^F\right) \end{cases}$$

By symmetry, we can develop portal 2's best response. The payoff functions and best responses of both portals are discontinuous in the service space (Figure 1a). We endogenize and identify bounds on portal parameters (the two MVIs) to determine which two types of portals can arrive at pure-strategy equilibrium. While algebraically tedious (hence the proof is relegated to the appendix), our approach provides lucid solutions to portal and regulator problems, allowing us to derive managerially relevant insights on portal competition under privacy.



(a) (b)

Figure 1. Asymmetric and Symmetric Equilibrium for Different Portal Types

Lemma 1: *When the MVI of one portal is low* $(\sigma_1 < 2b)$ and that of its competitor is sufficiently higher $\left(\sigma_2 \geq \frac{8b^2\sigma_1}{4b^2 - \sigma_1^2}\right)$, there exists an asymmetric equilibrium given by $\left(s_1^{F*}, s_2^{F*}\right) = \left(\frac{b\sigma_1\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}, \frac{2b^2\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}\right)$. Their respective profits $\left(\pi_1^{F*}, \pi_2^{F*}\right)$ are given in the appendix.

Lemma 1 states that in a competitive market for personalization where portals enforce usage agreement, the market will be served by two portals with distinctly different MVI in equilibrium. The portal with smaller MVI serves the segment of privacy seekers while its competitor serves the segment of convenience seekers. One can observe similarities between the above result and that from the traditional model of competition in a vertically segmented market with high and low product types under information asymmetry (Mussa and Rosen 1978). We could equate the distribution of consumers' break-even services to the distribution of consumers' reservation value in a pricing model, allowing the high type and low type portals to serve two different market segments. This result explains the coexistence of high MVI portals with superior consumer profiling abilities and vast advertising networks that offer wide arrays of personalized services (e.g., MSN''s news, weather, personal finance, and shopping services), and portals with low MVI that merely serve as conduits for advertising and rely on income from advertisers, offering only small subsets of services (e.g., Individual.com's personalized news).

It is interesting to note that the difference in equilibrium service offerings by the two portals diminishes as the marginal value for information of the low MVI portal approaches 2*b*: the portal with lower marginal value for information would increase the number of services offered while its competitor would react by *reducing* the number of services offered. The intuition is that, other things being constant, the portal with low MVI that was initially offering a subset of services at relatively low costs would find that the gains from additional customer information outweighs the costs of offering more services as its MVI increases. On the other hand, the portal with higher MVI would find it strategically advantageous to increase its competitiveness for consumers who have low p4p ratio by reducing the number of services, which at the same time increases the size of the captive segment of convenience seekers (albeit at the cost of obtaining less information from the individual consumers). Since consumers whose break-even level of services below $\frac{b\sigma_1\sigma_2}{4b(b+\sigma_2)+\sigma_1\sigma_2}$ would not enter the market, an interesting implication is that the higher the MVI of competing portals in the market, the larger the segment of privacy seekers that would be left out while the smaller the portion of convenience seekers that would be satisfied by the amount of personalization available. This finding leads us to an interesting prediction: as portals possess increasingly sophisticated profiling technologies and as the industry becomes increasingly aware of the potential of online advertising, personalization services offered by portals would be more and more similar, focusing on the needs of moderately convenience-seeking consumers and leaving those with relatively high privacy concerns out of the market.

An important question that follows this result is, what is the nature of competition when both portals have marginal values of information that are above or below the 2*b* threshold? The following two lemmas summarize the results from our analysis.

Lemma 2a: *In competition between two portals with high MVI, ($\{\sigma_1,\sigma_2\}\geq 2b$), there exists only a symmetric equilibrium given by* $s_F^* = \left(s_1^{F*}, s_2^{F*}\right) = \left(\frac{b}{3},\frac{b}{3}\right)$ *and their respective profits are* $\pi_1^{F*} = \frac{b(\sigma_1 - b)}{9}, \pi_2^{F*} = \frac{b(\sigma_2 - b)}{9}$.

Lemma 2b: *When both portals have low MVI ($\{\sigma_1,\sigma_2\} < 2b$), there exists* ***no symmetric*** *equilibrium even if their marginal values for information are identical.*

Lemma 2a suggests that when both portals have high MVI, the only feasible equilibrium is one 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 the portals need not have identical marginal values for information provided that they are sufficiently high (2*b* or above; see Figure 1b). A direct result is that when portals enforce usage agreement, regardless of how high above the threshold the MVI are for these competing portals, one-third of the market will always be left unserved. The intuition is that with high marginal values for information, portals would find it suboptimal to serve privacy seekers with a very low p4p ratio (less than $\frac{b}{3}$) because serving this segment of consumers implies offering a level of services so low that it prohibits them from obtaining sufficient information from the convenience seekers who are willing to use more services. On the other hand, offering a higher level of services would mean forgoing the entire segment of privacy seekers to the competitor whose service level becomes relatively lower. Therefore, no portal would deviate from the symmetric service level in equilibrium.

The results from lemma 2a have important implications in portals' incentives to employ trust-building mechanisms and protect consumer privacy. Prior research has shown that consumers' trust in a Web entity is strongly related to their privacy concerns in determining the usage of personalization services (Chellappa and Sin 2004). Hence investments in trust-building activities that help alleviate consumers' privacy concerns would have positive effects on the consumer's perception of personalization for privacy tradeoff (increase in p4p ratio), which in turn creates a positive influence on the consumer's usage of personalization services. Since the profits of both portals are strictly increasing in the consumer's p4p ratio, in a competitive market when both portals have high MVI, it is in the best interest of the portals to invest in safeguarding of consumer information beyond nominal compliance requirements set by a regulatory body such as the FTC and form alliances with trusted third parties.

Lemma 2b states that if the marginal values for information of both portals are sufficiently small, regardless of the actual differences, then a symmetric equilibrium does not exist (i.e., offering the same set of services is never optimal for both parties).

The intuition is that since consumers are indifferent between the services offered by the two portals, if the same number of services is being offered, both portals incur the full infrastructure costs of setting up the services while getting only half of the market. Since the marginal value for information is small, offering a slightly higher or lower service level becomes a weakly dominant strategy as it allows a portal to serve a consumer segment all by itself. Thus there is always a tendency to "undercut" the competitor by offering fewer services (at lesser costs but capturing all consumers with lower p4p ratios) or more services than the competitor (at greater costs but capturing all consumers with higher p4p ratios). Therefore, unless the two portals are sufficiently different in their marginal values for information (satisfying conditions given in lemma 1) that they can serve two distinct segments, no equilibrium is feasible if the MVI for both portals is low.

Portal Competition When Usage Enforcement Is Not Allowed (Neither Portal Enforces)

We now consider the more common scenario where portals are prohibited from (or incapable of) forcing consumers to use a certain number of services even if their utility is non-negative. Thus ,if available, consumers use only their optimal service level s_c^* and are indifferent between services offered by the two portals, i.e., both portals share the consumer segment with $s_c^* \le \min\{s_1, s_2\}$. The remaining consumers ($s_c^* > \min\{s_1, s_2\}$) 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 "higher" portal, and beyond which they can only use the exact amount that is offered. We can formally write portal 1's profit function as

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

By symmetry, portal 2's profit function can be constructed in a similar fashion. The best response functions are omitted here due to space limitation.

Lemma 3: *When portals cannot enforce usage and either* ***or*** *both portals have low MVI* (σ_1 or $\sigma_2 \le 2b$), *there exists* ***neither symmetric nor asymmetric*** *equilibrium even when their marginal values for information are identical* ($\sigma_1 = \sigma_2$). *When both portals have high MVI* ($\{\sigma_1, \sigma_2\} > 2b$), *there* exists a symmetric equilibrium *given by* $s_{NF}^* = \left(s_1^{NF*}, s_2^{NF*}\right) = \left(\dfrac{b}{2}, \dfrac{b}{2}\right)$ *and the profits are given in the appendix.*

Proposition 2: *In the absence of usage enforcement, when both portals' marginal values for information are high the equilibrium level of services maximizes consumer welfare.*

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, the portal offering the smaller number of services would essentially be sharing the market with its competitor who offers more services, while the latter enjoys the benefit of capturing the entire segment of consumers whose personalization needs are not satisfied by the other portal (i.e., those consumers with $s_c^* \in \left[\min\{s_1, s_2\}, \max\{s_1, s_2\}\right]$). This implies that offering more services than the competitor becomes the dominant strategy. Notice that since no consumer has s_c^* that is greater than $\dfrac{b}{2}$, no portal would offer services higher than this level. Hence, when marginal values for information are high enough for portals to compensate the cost of offering such high level of personalization, both portals would offer the maximum level of services desired by the consumers in equilibrium. Moreover, the equilibrium level of services is independent of portals' marginal values for information and the entire market is served with every individual consumer enjoying her ideal level of personalization. While this result is somewhat similar to that under enforcement presented in lemma 2a, in which only one-third of the market is served and the equilibrium profits of both portals are strictly increasing in consumer's p4p ratio, the implications on portals' incentives to engage in trust-building activities are quite different. In the absence of enforcement, portals would be interested in alleviating consumers' privacy concerns only when MVI of at least one of the portals is sufficiently high ($\sigma > 4b$). The reason is that improvements in consumers' perception of relative values for personalization to privacy risks imply higher equilibrium number of services; since the whole market is served and consumers are not constrained to use the entire set of personalization services offered, it becomes increasingly costly for portals to serve the privacy seekers. This negative effect on portals' profits can be compensated only if their MVI are above the $4b$ threshold.

Welfare Analysis and Policy Implications

Our results suggest that introduction of competition in the personalization market, while always improving consumer welfare, does not necessarily improve social welfare. Further, an additional tool for the regulator to influence welfare outcomes is through manipulation of usage enforcement. In this section, we summarize the analyses of consumer and social welfare under various market conditions.

Lemma 4: *For portals with very high marginal values for information* ($\sigma > 10b$), *producer, consumer, and social welfare in equilibrium is higher in the absence of enforcement than when usage enforcement is allowed.*

Lemma 4 suggests that usage enforcement is not necessarily beneficial even for portals under competition when their marginal values for information are large. The intuition behind this result is that, under usage enforcement, the equilibrium service level is limited to $\frac{b}{3}$. However, not only do some consumers prefer to use the full set of services $\left(\frac{b}{2}\right)$, but the high MVIs of portals also dictate a preference for larger number of services. Since we know that consumer welfare is maximized under no-enforcement competition, it is unambiguously a superior policy for the regulator to prohibit usage enforcement in a duopoly of portals with high marginal values for information. This finding is formally summarized in Proposition 3.

Proposition 3: *In a competitive market with portals that have high marginal values for information, consumer surplus is maximized even in the absence of policy that protects consumer rights to refuse service usage agreement.*

Next we turn to look at welfare from the society perspective and focus on portals with high marginal values of information. Assume now instead that the government engages in active protection of consumer rights by prohibiting portals' enforcement of consumer usage of services.

Proposition 4: *Social welfare is higher in a monopolistic market than in a competitive market when consumer's p4p ratio is diverse and usage enforcement is prohibited.*

Consistent with the findings in traditional economic analysis, in Web-based personalization markets, producer surplus under monopoly is always higher than that in a competitive environment, while consumer surplus is weakly higher under competition. The counterintuitive result of monopolistic market outperforming competitive market in terms of social welfare can be explained by the difference in the gains in producer surplus and losses in consumer surplus: in a competitive environment, both portals incur the same infrastructure costs in providing an identical set of personalization services while sharing the revenue with the competitor due to the absence of usage enforcement. Given that marginal cost of online personalization is negligible, the fixed costs play a significant role in producer surplus and the monopoly essentially *reduces* the deadweight loss in the system by reducing the overall fixed costs of providing personalized services, hence promoting social welfare.

Discussion and Conclusions

In this paper, we study the Web-based personalization market in both monopolistic and competitive settings. In particular, we investigate implications of the revenue model of online personalization services and realistically represent consumer utility in a non-monotonic concave form that is unique to our setting.

Our finding of the existence of asymmetry equilibrium between portals with different MVI provides insights as to why smaller portals, such as citisearch.com and individual.com, which offer a limited set of personalization options, can survive in the presence of gigantic portals such as Yahoo! and MSN, which offer a fuller range of personalized services from weather to movies and even financial tools. The main reason is that portals with sufficiently different MVIs serve two distinct segments of consumers, namely, privacy seekers and convenience seekers, and maintain monopolistic advantage in their respective territories. Further, our investigation of the underlying dynamics leads to the prediction of convergence in personalization services that focus on the needs of moderately convenience-seeking consumers.

Interestingly, we find that in the absence of usage enforcement, the only feasible equilibrium outcome is one that maximizes consumer welfare with both portals offering the full set of personalized services. While we find comparable results under enforcement when portals' MVI are sufficiently high, the implications on portals' incentive to invest in trust-building mechanisms vary. We show that while in the former case portals with high MVI have mutual interest in improving consumers' perception of the value-to-risk tradeoff in using personalization services, in the latter case this is true only for portals with even higher marginal value for information.

Out welfare analysis reveals that while consumer surplus is weakly higher under competition, social welfare can potentially be maximized in a monopolistic market. Although the net effect of usage enforcement on social welfare is ambiguous, we find that monopoly outperforms competition under certain circumstances and that producer surplus can be higher in the absence of enforcement when competing portals have high enough MVI.

Our current focus is limited in that usage enforcement is given as an exogenous constraint rather than a strategic variable. Realistically, with sophisticated tracking and profiling technologies, portals can potentially decide whether or not to enforce usage agreement. Future research can incorporate enforcement as a portal strategy and may arrive at some interesting outcomes. For example, it may be in the best interest of the high MVI portal to allow consumers to freely choose their ideal service levels, forcing the portals with small MVI to also forgo enforcement and share the otherwise captive privacy seekers segment in which case the viability of the low MVI portal becomes questionable.

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Appendix

Proof of Proposition 1

The monopoly's profit function does not change whether enforcement is feasible or not:

Enforcement: $\pi_m^F = \sigma \int_s^b sf\left(s_c^0\right) ds_c^0 - s^2 \Rightarrow \sigma s\left(\frac{b-s}{b}\right) - s^2$;

No enforcement: $\pi_m^{NF} = \sigma\left(\int_o^s f\left(s_c^*\right) ds_c^* + \int_s^{\frac{b}{2}} sf\left(s_c^*\right) ds_c^*\right) - s^2 \Rightarrow \frac{\sigma s\left(b-s\right)}{b} - s^2$.

Solving for optimal *s*, we get the monopoly service and profits as $s_m^F = s_m^{NF} = \frac{b\sigma}{2\left(\sigma+b\right)}, \pi_m^F = \pi_m^{NF} = \frac{b\sigma^2}{4\left(b+\sigma\right)}$

Proof of Lemma 1: Asymmetric equilibrium in the enforcement case

We shall find $\left\{s_1^{F*}, s_2^{F*}\right\}$ and verify that this pair of services is indeed an equilibrium, i.e., the necessary conditions for portal 1 are

$$\pi_{1a}^F\left(s_1^{F*}, s_2^{F*}\right) \geq \pi_{1b}^F\left(s_1^F = s_2^{F*}\right) \qquad \text{(A1)}$$

$$\pi_{1a}^F\left(s_1^{F*}, s_2^{F*}\right) \geq \pi_{1c}^F\left(s_1^F > s_2^{F*}\right) \qquad \text{(A2)}$$

Solving $BR_{1a}^F = BR_{2c}^F$ yields $\left(s_1^{F*}, s_2^{F*}\right) = \left(\frac{b\sigma_1\sigma_2}{4b\left(b+\sigma_2\right)+\sigma_1\sigma_2}, \frac{2b^2\sigma_2}{4b\left(b+\sigma_2\right)+\sigma_1\sigma_2}\right)$ and

$\left(\pi_1^{F*}, \pi_2^{F*}\right) = \left(\frac{b^2\sigma_1^2\sigma_2^2}{\left[4b\left(b+\sigma_2\right)+\sigma_1\sigma_2\right]^2}, \frac{4b^3\sigma_2^2\left(b+\sigma_2\right)}{\left[4b\left(b+\sigma_2\right)+\sigma_1\sigma_2\right]^2}\right)$. Now we need to verify that $\left\{s_1^{F*}, s_2^{F*}\right\}$ satisfies both (A1) and (A2). Incorporating the equilibrium services in portal 1's profit functions and simplifying (A2), we have $\frac{2b^3\sigma_2\left(2b\sigma_2-2b\sigma_1-\sigma_1\sigma_2\right)}{\left(4b^2+4b\sigma_2+\sigma_1\sigma_2\right)^2} \geq 0$, or $\sigma_2 \geq \frac{2b\sigma_1}{2b-\sigma_1}$. In order to find the competing portal characteristics that satisfy equation (A2), we shall first eliminate those portal types for whom this condition will not be met i.e., we shall identify σ_1, σ_2 for whom $\pi_{1a}^F\left(s_1^{F*}, s_2^{F*}\right) < \pi_{1c}^F\left(s_1^F > s_2^{F*}\right)$ or as simplified below in equation (A3).

$$s_1^F\left[\sigma_1 - \frac{s_1^F\left(b+\sigma_1\right)}{b} - \frac{2b\sigma_1\sigma_2}{4b\left(b+\sigma_2\right)+\sigma_1\sigma_2}\right] - \frac{b^2\sigma_1^2\sigma_2^2}{\left[4b\left(b+\sigma_2\right)+\sigma_1\sigma_2\right]^2} > 0 \qquad \text{(A3)}$$

Reducing (A3) to a quadratic expression and solving for s_1^F, we get $\sigma_2 < \dfrac{8b^2\sigma_1}{4b^2 - \sigma_1^2}$. Hence the necessary conditions for the existence of an asymmetric equilibrium are given by $\sigma_1 < 2b,\ \ \sigma_2 \geq \dfrac{8b^2\sigma_1}{4b^2-\sigma_1^2}$ Performing similar operations for portal 2, we can verify that these conditions are indeed necessary and sufficient.

Proof of Lemmas 2a and 2b

Let there be a symmetric equilibrium given by $s_1^{F*} = s_2^{F*}$ such that $\pi_1^F\left(s_1^{F*}, s_2^{F*}\right) \geq \pi_1^F\left(s_1^F, s_2^{F*}\right)$ and $\pi_2^F\left(s_1^{F*}, s_2^{F*}\right) \geq \pi_2^F\left(s_1^{F*}, s_2^F\right)$. For portal 1 the above implies $\pi_{1b}^F\left(s_1^{F*}, s_2^{F*}\right) \geq \pi_{1a}^F\left(s_1^F < s_2^{F*}\right)$ and $\pi_{1b}^F\left(s_1^{F*}, s_2^{F*}\right) \geq \pi_{1c}^F\left(s_1^F > s_2^{F*}\right)$. First consider $s_1^F > s_2^{F*}$, i.e., $s_1^F = s_2^{F*} + k$ where $k > 0$. For $\pi_{1b}^F\left(s_1^{F*}, s_2^{F*}\right) - \pi_{1c}^F\left(s_1^F > s_2^{F*}\right) \geq 0$, we need

$$\frac{2bk^2 + 4bks_1^F - 2bk\sigma_1 + 2k^2\sigma_1 - b\sigma_1 s_1^F + 6k\sigma_1 s_1^F + 3\sigma_1 {s_1^F}^2}{2b} \geq 0 \qquad \text{(A4)}$$

We can see that equation (A4) will be true only if $s_1^F \geq \dfrac{b}{3}$. Next consider $s_1^F < s_2^{F*}$, i.e., $s_1^F = s_2^{F*} - l$ where $l > 0$. By similar procedures, we can show that $\pi_{1b}^F\left(s_1^{F*}, s_2^{F*}\right) \geq \pi_{1a}^F\left(s_1^F < s_2^{F*}\right)$ will be true only if $s_1^F \leq \dfrac{b}{3}$, with the necessary condition that $\sigma_1 \geq 2b$. By symmetry, we can derive the conditions for portal 2. This implies that when both portal parameters are given by σ_1, σ_1, $\geq 2b$, the symmetric equilibrium and respective profits are given by $\left(s_1^{F*}, s_2^{F*}\right) = \left(\dfrac{b}{3}, \dfrac{b}{3}\right)$; $\left(\pi_1^{F*}, \pi_2^{F*}\right) = \left(\dfrac{b(\sigma_1 - b)}{9}, \dfrac{b(\sigma_2 - b)}{9}\right)$. Since we derive the portal parameters endogenously, we can see that the equilibrium (symmetric or asymmetric) exist only when σ_1, $\sigma_2 \geq 2b$ or when $\sigma_1 < 2b,\ \ \sigma_2 \geq \dfrac{8b^2\sigma_1}{4b^2-\sigma_1^2}$.

Proof of Lemma 3

Similar to enforcement case, we shall endogenously determine the combination of portal parameters for which an equilibrium solution exists. We begin by exploring the existence of symmetric equilibria. Let the symmetric equilibrium be given by $s_1^{NF*} = s_2^{NF*}$ such that $\pi_1^{NF}\left(s_1^{NF*}, s_2^{NF*}\right) \geq \pi_1^{NF}\left(s_1^{NF}, s_2^{NF*}\right)$ and $\pi_2^{NF}\left(s_1^{NF*}, s_2^{NF*}\right) \geq \pi_2^{NF}\left(s_1^{NF*}, s_2^{NF}\right)$. We can break down portal 1's analysis into two cases as before, i.e., $\pi_{1b}^{NF}\left(s_1^{NF*}, s_2^{NF*}\right) \geq \pi_{1a}^{NF}\left(s_1^{NF} < s_2^{NF*}\right)$ and $\pi_{1b}^{NF}\left(s_1^{NF*}, s_2^{NF*}\right) \geq \pi_{1c}^{NF}\left(s_1^{NF} > s_2^{NF*}\right)$. First consider $s_1^{NF} > s_2^{NF*}$, $s_1^{NF} = s_2^{NF*} + k$ i.e., for some $k > 0$. For $\pi_{1b}^{NF}\left(s_1^{NF*}, s_2^{NF*}\right) \geq \pi_{1c}^{NF}\left(s_1^{NF} > s_2^{NF*}\right)$, we need

$$\frac{2bk^2 + 4bks - 2bk\sigma_1 + 2k^2\sigma_1 - b\sigma_1 s_1^{NF} + 4k\sigma_1 s_1^{NF} + 2\sigma_1 {s_1^{NF}}^2}{2b} \geq 0 \qquad \text{(A5)}$$

We can see that equation (A5) is true only if $s_1^{NF} \geq \dfrac{b}{2}$. Similarly, consider $s_1^{NF} < s_2^{NF*}$, i.e., $s_1^{NF} = s_2^{NF*} - l$ for some $l > 0$, then for $\pi_{1b}^{NF}\left(s_1^{NF*}, s_2^{NF*}\right) \geq \pi_{1a}^{NF}\left(s_1^{NF} < s_2^{NF*}\right)$, we need

$$\frac{2bl^2 - 4bls_1^{NF*} - l^2\sigma_1 + b\sigma_1 s_1^{NF*} + 2l\sigma_1 s_1^{NF*} - 2\sigma_1 s_1^{NF*2}}{2b} \geq 0 \tag{A6}$$

(A6) is true only if $s_1^{NF} \geq \dfrac{b}{2}$ with the necessary condition that $\sigma_1 > 2b$. Also note that $\frac{b}{2}$ is the maximum level of service that any portal would offer in the market as the s_c^* of the consumer with the highest $\frac{p}{r}$ ratio is $\frac{b}{2}$, i.e., there is no consumer in the market who will use any service level greater than this bound. We can similarly derive portal 2's strategy by symmetry, and hence conclude that a symmetric equilibrium exists for portal parameters given by $\sigma_1, \sigma_2 > 2b$, where the equilibrium service-pair and the respective profits of the two portals are $\left(s_1^{NF*}, s_2^{NF*}\right) = \left(\dfrac{b}{2}, \dfrac{b}{2}\right)$; $\left(\pi_1^{NF*}, \pi_2^{NF*}\right) = \left(\dfrac{b(\sigma_1 - 2b)}{8}, \dfrac{b(\sigma_2 - 2b)}{8}\right)$. Note that when $\sigma_1 < 2b$, portal 1 will never opt to offer services less than his competitor as π_{1a}^{NF} is negative. By symmetry this implies that when $\sigma_2 < 2b$, portal 2 will also not consider offering services less than his competitor and thus asymmetric equilibrium cannot exist if either or both σ of the portals are $2b$. Further, from our earlier discussion, we know that for symmetric equilibrium, the non-negative profit condition requires that a portal's marginal value for information be greater than or equal to $2b$; hence, we know that there cannot exist any equilibrium when $\sigma_1, \sigma_2 < 2b$.

Proof of Proposition 2:

Notice that the equilibrium service level $\left(s_1^{NF*}, s_2^{NF*}\right)$ is exactly the consumer welfare-maximizing level under no enforcement in which all consumers can choose their respective utility-maximizing services, with the highest s_c^* being $\frac{b}{2}$. Q.E.D.

Proof of Lemma 4:

From lemmas 2a and 3b, we know that $\pi_i^{NF*} > \pi_i^{F*}$ iff $\sigma_i > 10b$, $i = \{1,2\}$. Q.E.D.

Proof of Proposition 4:

Consumer welfare is maximized under competition with no enforcement. Let this be denoted by W_c^*. Assume for simplicity that the information requirements for the competing portals to be the same as that of the monopoly. The total producer surplus in the competitive market is $\dfrac{b(\sigma - 2b)}{4}$, yielding a social welfare of $W_c^* + \dfrac{b(\sigma - 2b)}{4}$. The loss in consumer surplus in the monopoly market is given by $\int_s^{\frac{b}{2}} (x - s)\, f\left(s_c^*\right) ds_c^* \Rightarrow \dfrac{b^3}{4(b+\sigma)^2}$ and the producer surplus is $\dfrac{b\sigma^2}{4(b+\sigma)}$, yielding a social welfare of $W_c^* + \dfrac{b\sigma^2(b+\sigma) - b^3}{4(b+\sigma)^2}$. The social welfare generated in the monopolistic market is higher than that generated in the competitive market when $\sigma > \dfrac{1}{2}\left(\sqrt{4b + b^2} - 3b\right)$, which is always true if $b > \dfrac{1}{2}$.