Privacy, Customization, and Cross-Selling of Information

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ABSTRACT

An unavoidable aspect of electronic commerce is the collection of personal information. Although personal information is paramount to improving services and designing personalized offerings, its collection and use also generates privacy concerns. This study analytically examines the optimal information collection and usage practices in the presence of privacy costs. We use an analytical model in which a firm makes decisions on pricing, level of information collection and customization, and the extent of cross-selling. We find that cross-selling opportunities create value for consumers and sellers since consumer surplus and total profits may both increase with cross-selling. Advances in information technology motivate cross-selling and provides more incentives for the firms to engage in cross-selling. Consequently, firms are better off when cross-selling while offering customized products even in the presence of privacy costs. We find that serving a niche market and limiting the demand is a winning strategy when consumers' value for customization increases. On the other hand, an increase in the profitability of cross-selling favors a mass market strategy where a firm serves a broader range of customers. Interestingly, cross-selling strategies may lower prices and provide significant strategic advantages with increased customer satisfaction while reaching a broader market. Total surplus increases at a decreasing rate as the amount of information collection and the extent of cross-selling increase. A niche marketing strategy facilitated by improvements in customization technology increases both consumer and total surplus.

Keywords: Privacy, customization, personalization, cross-selling, electronic commerce

I. INTRODUCTION

Successful firms increasingly adopt e-commerce to collect vast amounts of customer information [1]. Obtaining customer data has a strategic priority. When firms obtain intimate customer data, they can offer superior personalized services that boost consumer value and loyalty [2]. In addition, they can share their customer data with third parties[1] and boost their profits due to cross-selling. In return, consumers who value their privacy and do not want to share their information may hesitate to reveal their information [3]. Consequently, success in information-intensive environments depends on firms' ability to respond to such privacy concerns while discovering the right targeting and customization strategies [4, 5].

Consumers weigh the benefits and risks when revealing their information [6]. When firms create superior value with personalization and mitigate privacy concerns, revealed information provides additional benefits to consumers [7, 8], while a true understanding of customers' needs and preferences allows merchants to identify superior cross-selling opportunities and increase profits [9, 10]. However, identifying the right emphasis and the extent of cross-selling can be a challenge. In addition, a customer may have different preferences for sharing information when a customer perceives higher risks. For example, customers may be more sensitive when revealing information that may be used in financial and healthcare related services.

In this paper, we analytically examine the optimal level of customization and the extent of cross-selling of products and services in the presence of privacy concerns. We hypothesize that variation in privacy concerns and customization benefits, coupled with different cross-selling opportunities, strongly impact optimal firm-level strategies. Specifically, we examine the

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[1] Third parties mean other firms as well as other departments in a large firm.

following research questions: To what extent should firms collect personal information for product customization given the personal cost of privacy violations? How does the profitability of cross-selling in an industry affect the optimal pricing and information collection strategies of firms? What is the impact on a firm's customer targeting strategy? What are the implications of these strategies on overall welfare?

We use a stylized analytical framework that allows for different customization value – privacy cost trade-offs. A firm collects personal information to increase the value of its product for the consumers through customization. The amount of information revealed by the consumers is a direct measure of the level of information utility. A customer's information utility is defined by customization valuation minus privacy costs. Receiving customized offerings provide positive surplus for the customers. From a firm's point of view, providing customized offerings require incurring a customization cost, but it also motivates customers to reveal information. Revealed information may be cross-sold and such cross-selling activities provide the firm with another revenue stream (in addition to the sale of its product). On the other hand, cross-selling activities pose a privacy risk for the customers. Consequently, the firm has to acknowledge customer privacy concerns while collecting information. There are two sources of consumer heterogeneity. The first source of heterogeneity captures differing customization valuations. The second source of heterogeneity is related to the differing privacy concerns of consumers.

We find that cross-selling opportunities create value for consumers and sellers since consumer surplus and total profits may both increase with cross-selling. Advances in information technology motivate cross-selling and provide more incentives for the firms to engage in cross-selling. Consequently, firms are better off when cross-selling while offering customized products even in the presence of privacy costs. Our results also demonstrate the

intricate relationship between the optimal cross-selling activities and their profitability. Interestingly, as the profitability of cross-selling increases, the firm may limit its cross-selling activities. We also find that the optimal demand that the firm faces may drop due to an increase in the value of customization. Serving a niche market and limiting the demand is a winning strategy when consumers' value for customization increases. On the other hand, an increase in the profitability of cross-selling favors a mass market strategy where a firm serves a broader range of customers. We also find that cross-selling strategies may lower prices and provide significant strategic advantages such as raising customer satisfaction while reaching a broader market. Total surplus increases at a decreasing rate as the amount of information collection and the extent of cross-selling increase. A niche marketing strategy facilitated by improvements in customization technology increases both consumer and total surplus.

We next review the related literature. We describe the theoretical model in Section 3 and present the analysis and results in Section 4. We conclude the paper with a discussion of the results, implications, and directions for future research.

II. LITERATURE REVIEW

The current work is particularly related to three main bodies of research: personalization-privacy paradox, economics of privacy, and customization. Research on personalization-privacy paradox is mainly empirical, while the related studies on economics of privacy and those on customization are predominantly analytical. We briefly discuss important studies in these three areas of research.

A. Personalization-Privacy Paradox

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Personalization-privacy paradox is an outcome of electronic commerce. Due to the ease of collecting personal information through the Internet, offering personalized products and services is fast becoming the norm rather than the exception. However, implicit in the collection and use of consumer information is a concern for privacy, hence the paradox faced by firms [2]. Studies in this area explore issues dealing with the best procedures for collecting personal information and balancing privacy concerns and information collection for personalization purposes.

Before a firm can optimize its information collection practices, it has to first understand the level of privacy concern among its customers. Malhotra et al. [11] develop a scale for a multidimensional construct for privacy concerns online, and propose and test a causal model that aims to explain the antecedents of the behavioral intention to release personal information at the request of a marketer. The researchers empirically show the important role of privacy concerns for e-commerce firms. Culnan and Armstrong [1] focus on the tension that arises between the collection and use of personal information by firms and consumers' privacy concerns. Their study confirms the hypothesis that organizations can address these privacy concerns and retain customers. In a similar vein, Dinev and Hart [3] argue that consumers weigh the benefits and costs of information disclosure. Using a theoretical model called "privacy calculus," they show that the positive effect of trust and personal Internet interest on e-commerce transactions can be more important than that of privacy costs. In another related study, Hann et al. [12] explore individuals' trade-offs between the benefits and costs of disclosing personal information to websites, and conservatively estimate that consumers' value for privacy ranges from $45 to $57. Using survey data, Chellappa and Sin [13] show that consumers place different values on personalization and that online vendors can gather more customer information if they engage in trust building activities. Further empirical studies also provide support on the importance of

privacy and information management practices and that customers consider both costs and benefits when revealing information and paying a price online [6, 2]. In our analytical model, customers weigh the benefits and costs of disclosing personal information. We allow firms to alleviate consumers' concerns by choosing not to share their information with third parties. We also allow firms to compensate customers for revealing their information by charging lower prices.

B. Economics of Privacy

Economic studies on privacy are concerned with the effect of information collection, secondary use of information, and privacy regulation on social welfare. Past studies report mixed results on the effect of information collection on social welfare (see, for example [14]). Hermalin and Katz [15] show that an increase in the quantity of personal information might *reduce* welfare, and therefore protecting privacy might raise welfare. On the other hand, Acquisti and Varian [16] demonstrate that the collection of personal information could *raise* welfare when sellers price discriminate across different types of consumers. Calzolari and Pavan [17] model the exchange of information between two sellers who contract sequentially with the same buyer. They show that offering the buyer full privacy is optimal, although they also find cases in which information disclosure yields a Pareto improvement.

Firms may use personal information for secondary purposes where they collect information in one market and sell it to internal and external entities in other markets. When secondary use is a possibility, firms may have an excessive incentive to collect personal information at the expense of their potential customers [18]. Therefore, depending on the composition of the consumer population, secondary use of information may reduce social

welfare due to the cost of compiling the information and the loss in transactions given sellers' incentive to increase price in an attempt to categorize consumers [19].

In our study, we posit that information collection is linked to increased value, which can vary substantially, through product customization. In line with the above stream of research, we model privacy sensitivity of consumers and analyze the welfare impacts of information exchange in the presence of cross-selling. In our setting, cross-selling provides the firm an additional incentive to collect personal information. However, this also increases the privacy cost that consumers incur depending on the use of information.

C. Customization

The strategic importance of customization has drawn significant academic scrutiny. In their review of research on personalization and customization, Murthi and Sarkar [20] argue that the real constraint firms face in increasing the value of their products is the availability of customers' personal information. The value of customization is further emphasized by Dellaert and Stremersch [21], who conduct an experimental study about the effect of product utility and complexity on the utility that consumers derive from customization, and find that product utility has a positive effect while product complexity has a negative effect on customization utility.

Among the analytical studies on this topic, Dewan et al. [22] uses a duopoly setting to show that early adoption of customization can lead to a competitive advantage. They also find that sellers customize their products excessively when they adopt customization, putting themselves in a worse situation than when they don't offer custom products (a situation also known as the "prisoner's dilemma"). Syam et al. [23] use a duopoly setting to show the interesting result that consumer surplus can actually drop as a result of customization. In another analytical study, Cavusoglu et al. [24] investigate optimal customization strategies and find that

customization does not lead to an escalation in price competition. They also show that customers are better off on average when firms adopt customization than when they do not. On the other hand, unless customization costs little, total firm profits in the market drops as a result of customization.

III. MODEL

Consider a firm that makes strategic decisions on the extent of information collection and customization, the extent of cross-selling to third parties, and price, to maximize its profit. The firm requires the same level of information across all the customers to offer a customizable product. A fraction of the information obtained may be cross-sold. Given such strategic decisions by the firm, customers maximize their surpluses by deciding whether or not to engage in the offering and interact with the firm.

There are two sources of revenue for the firm: the sale of its customized product and cross-selling. As suggested by Resnick and Varian [25], the firm imposes sharing a certain level of information as a mandatory requirement for receiving a custom product, and obtains revenue from the sale of this product by charging a price p. Cross-selling provides a second source of revenue. Cross-selling activities include marketing of other products and services by the firm and its subsidiaries as well as the sale of customer information itself. Similar to Akçura and Srinivasan [26] and Chen and Ghose [27], the revenue from cross-selling is assumed to be proportional to the amount of information being collected (i) and the extent of cross-selling activity (s). The extent of cross-selling represents the percentage of personal information cross-sold to other departments within the firm and to other entities. A high level of s indicates that most of the obtained information is cross-sold. There is a natural boundary on the amount that

can be cross-sold; when s equals to one all the available information is cross-sold. A low level of s indicates that only a limited amount of information is being cross-sold. At a minimum level, the firm can provide just the customer identification and contact information in order to engage in cross-selling. Hence, if s is lower than a threshold level $\underline{s}$, $\underline{s} > 0$, the limited nature of information does not provide an attractive revenue stream, and cross-selling is not profitable; we therefore assume $1 > s \geq \underline{s}$. Cross-selling revenue also varies depending on whether personal information is allowed to be used for targeting purposes for products and services in a given business context. For example, when a firm learns that a customer frequently visits Florida, a sufficiently high s may trigger the decision to cross-sell this information, which can then be used for targeting a variety of offerings such as financial, healthcare or travel related services. The exact nature of these targeting activities depends on contractual agreements and firm-specific environments where firms may not have much control over. We therefore introduce an exogenous parameter k that captures the value of cross-sold personal information. When a firm cross-sells in a variety of industries, the parameter k captures the average value that a firm obtains in return for the cross-sold information across these industries. Engaging in cross-selling activities may also require incurring additional costs specific to such activities. For example, the firm may need to invest in additional information technology, sales people, servers, database systems, and storage. In such cases, k represents the value of information net of any costs or commissions. When such costs are high, the net value of cross-sold personal information is significantly limited, and k is close to zero. Since the firm obtains a profit of k from a unit of cross-sold information, we henceforth refer to k as the unit cross-selling profit.

The firm has to develop necessary customization technologies for the product based on the extent of the required customer information. This results in incurring a fixed product

development cost depending on the intended level of customization. When the customers reveal limited information, the extent of customization and its associated product development cost are also limited. A higher level of customer information is associated with extensive customization effort, which raises the customization level and product development costs. As in Dewan et al. [22] and Syam and Kumar [28], we assume that customization is costly, and that the marginal cost of a customized product is increasing and convex in the degree of customization. Let i represent the amount of customer information that the firm collects. Then, the firm incurs a cost ci^2, with c being a cost parameter, $c > 0$. The squared term in the cost expression implies that higher levels of information collection and personalization require increasingly larger customized product development budgets for the firms. In addition to the fixed cost of product development, the firm may also incur a variable cost which may include the cost of transacting with the customer. Our model can easily handle such costs; the intuition and arguments still continue to hold with these costs. However, since advances in information technology, automation, and artificial intelligence tend to mitigate the role of such costs, we normalize them to zero for simplicity and ease of exposition. Given the revenues from the sale of customized products (p) and cross-selling (ksi), we have the following profit function:

$$\Pi(i,s,p) = (p + ksi)D(i,s,p) - ci^2, \qquad (1)$$

where $D(i,s,p)$ denotes the demand.

Consumers differ on two dimensions: the valuation they have for the customized product and the privacy cost they incur due to information sharing and cross-selling. Every customer has to reveal a certain level of information i in order to receive the customized product; this level is the same for all customers. The extent of customization increases with the amount of customer information i. We let the average value of the customized product to be proportional to αi,

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where the parameter α represents the relative value of customization. Note that α should be sufficiently large for the customers to participate in the customized offer their demand to respond to price changes (i.e., to ensure a downward slope with respect to price),. Consumers' value for customized offerings can also vary. Differences in valuations for product customization could arise due to differences in consumers' tastes or incomes. We use the parameter $\theta \in [0,1]$ to capture the customization-based consumer differentiation, where consumers with higher θ value the customized product more. Consumers' value for the personalized product of the firm is thus given by $\theta \alpha i$.

Customers incur privacy costs when their information is cross-sold. Studies have shown that consumers differ in their concerns for their privacy and that they incur different costs when their privacy is violated [12]. Variations in privacy costs could be due to consumers' incomes and their risk perceptions toward technology and e-commerce applications. We use the parameter $\beta \in [0,1]$ to capture the privacy-based consumer differentiation, where consumers with a higher β incur higher privacy costs as a result of cross-selling. Customers know the extent of cross-selling. For example, the number of targeted messages being received, transparent information management practices and privacy policies may result in customers observing the firm's cross-selling strategies. When only a limited amount of information is cross-sold, customers may not have significant adverse costs. However, as their information is exploited at higher rates, customers' privacy costs are likely to increase significantly. In order to capture this sensitivity, we let privacy costs to increase in proportion to the squared term of the shared information, s^2. Further, some firms may be interested in collecting more sensitive (such as financial or health-related) information. In some cases the privacy cost to an individual may be much more than the value of the information to a business. For example, the sale of an

individual's medical information, although valuable to insurers, can be extremely costly for its owner if such sale prevents that individual from buying health insurance in the future. On the other hand, the sale of information about a person's past shopping history would probably not be as detrimental to him or her, although such information is still valuable for firms whose products and services would appeal to this person. In order to capture such variations, we let the privacy cost to vary with k according to the functional form $g(k)$, where $g(k) > 0$ characterizes the magnitude of privacy sensitivity.[2] Consequently, the privacy cost arising from information collection and cross-selling is defined as $\beta s^2 g(k) i$.

Consumers' information utility equals to the value from customization less privacy costs. In this formulation, information utility equals $\left(\theta \alpha - \beta s^2 g(k) \right) i$ where (θ, β) are distributed uniformly over the unit square, with a total mass equal to one. Hence, consumer surplus for purchasing the personalized product at price p equals

$$U(i, s, p) = \left(\theta \alpha - \beta s^2 g(k) \right) i - p. \tag{2}$$

For the customer to engage in the personalized offer, the firm has to deliver a higher surplus than a competing alternative's surplus which we denote as $\underline{U}$. $\underline{U}$ may correspond to a standard, non-customized product's surplus which we normalize at zero. In other words, the firm has to deliver a positive surplus for a consumer to participate in the firm's customized product offer. The firm sets its strategy that maximizes its profit while knowing customer heterogeneity. Customers then decide whether to participate in the firm's offer. We analyze the pure strategy equilibrium and provide the solutions in the next section.

IV. ANALYSIS

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[2] It is conceivable that consumers may not precisely observe the privacy risks when dealing with a firm and instead form expectations about those privacy risks. The model can accommodate such situations through a flexible definition of $g(k)$. Depending on customer expectations about privacy costs, $g(k)$ may take small or large values.

We first present the solution of the model. In order to maximize the profit, we need to identify the demand. The θ value for the consumer who is indifferent to purchasing the product is found by setting the utility to zero:

$$\underline{\theta} = \frac{\beta s^2 i g(k) + p}{i\alpha}. \tag{3}$$

The total demand for the product is

$$D(i,s,p) = \int_0^1 \int_{\underline{\theta}}^1 d\theta \, d\beta = 1 - \frac{s^2 i g(k) + 2p}{2i\alpha}. \tag{4}$$

Plugging this expression in the profit equation (1) above we obtain

$$\Pi(i,s,p) = (p + ksi)\left(1 - \frac{s^2 i g(k) + 2p}{2i\alpha}\right) - ci^2. \tag{5}$$

Simultaneously solving for the profit-maximizing first-order conditions, we find the optimal outcomes. The profit maximizing cross-selling activity for an internal solution calls for setting $s^* = \dfrac{k}{g(k)}$, where $1 > \dfrac{k}{g(k)} > \underline{s}$. However, when $\underline{s} > \dfrac{k}{g(k)}$, the firm has an option of either not cross-selling or engaging in a minimum of $\underline{s}$ level of cross-selling. We see that given a cross-selling activity of s, the optimal solution is given by the following (see Appendix for details):

$$i^* = \frac{\left(2\alpha - s^2 g(k) + 2ks\right)^2}{32\alpha c}, \tag{6}$$

$$p^* = \frac{\left(\left(2\alpha - s^2 g(k)\right)^2 - 4k^2 s^2\right)^2}{128\alpha c}, \tag{7}$$

$$\Pi^* = \frac{\left(2\alpha - s^2 g(k) + 2ks\right)^4}{1024c\alpha^2}. \tag{8}$$

When there is no cross-selling and s is set to zero, the firm obtains a profit of $\dfrac{\alpha^2}{64c}$ (see Equation 8). Consequently, the firm offers a personalized product, and the information revealed by customers is used strictly for providing customized offerings. We find that the firm collects information $\dfrac{\alpha}{8c} > 0$ (see Equation 6) and charges a price of $\dfrac{\alpha^3}{8c}$ (see Equation 7) with no cross-selling. On the other hand, with the minimum cross-selling activity of $\underline{s}$, the firm can do even better and increase its profit. In specific, the profit equals to $\dfrac{\left(2\alpha - \underline{s}^2 g(k) + 2k\underline{s}\right)^4}{1024c\alpha^2}$ with $s = \underline{s}$.

Given a sufficiently small $\underline{s}$ such that $\dfrac{2k}{g(k)} > \underline{s}$, $\dfrac{\left(2\alpha - \underline{s}^2 g(k) + 2k\underline{s}\right)^4}{1024c\alpha^2} > \dfrac{\alpha^2}{64c}$. Hence, the firm increases its profit and always engages in cross-selling as long as $\dfrac{2k}{g(k)} > \underline{s}$. Total consumer surplus is calculated as $CS = \int_0^1 \int_{\underline{\theta}}^1 \left(\theta \alpha i - \beta s^2 g(k) i - p\right) d\theta\, d\beta$. We thus have our first result. All proofs are in the Appendix.

Proposition 1. *Given a sufficiently small $\underline{s}$ such that $\dfrac{2k}{g(k)} > \underline{s}$, the firm always engages in cross-selling activity when offering a customized product. The firm cross-sells the minimum required level when $\underline{s} > \dfrac{k}{g(k)} > \dfrac{s}{2}$. When $1 > \dfrac{k}{g(k)} > \underline{s}$, the internal solution calls for*

$$i^* = \frac{\left(2\alpha g(k) + k^2\right)^2}{32\alpha c g(k)^2},\tag{9}$$

$$p^* = \frac{\left(2\alpha g(k) + k^2\right)^2 \left(2\alpha g(k) - 3k^2\right)}{128\alpha g(k)^3 c},\tag{10}$$

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$$s^* = \frac{k}{g(k)} \qquad (11)$$

$$D^* = \frac{1}{2} + \frac{k^2}{4\alpha g(k)}, \qquad (12)$$

$$\Pi^* = \frac{\left(2\alpha g(k) + k^2\right)^4}{1024 c \alpha^2 g(k)^4}, \qquad (13)$$

$$CS = \frac{\left(2\alpha g(k) + k^2\right)^2 \left(12\alpha^2 g(k)^2 + 12k^2 \alpha g(k) + 7k^4\right)}{3072 c \alpha^2 g(k)^4}. \qquad (14)$$

The above proposition provides an intuition on why successful firms increasingly focus on cross-selling as information technology advances. According to the proposition, cross-selling becomes profitable when $\underline{s}$ is sufficiently low such that $\frac{2k}{g(k)} > \underline{s}$. There are many examples of information-intensive environments where firms easily obtain and leverage customer-specific information. For example, cookies and advanced information and targeting technologies help firms easily identify customer footprints. As a result, firms can profit from cross-selling even by just tracking their customers' browsing activities. In addition, targeted offerings and ads from third parties provide significant opportunities for many web sites. Such cross-selling opportunities provide additional incentives to capture customer information and engage in customization. Through cross-selling and offering customized products, firms increase their profits and benefit from new sources of revenues and growth. In return, the resulting perception of superior benefits and improved customer relationships tend to increase customer loyalty.

Information-intensive environments can also help firms offer superior customization value at lower costs, which gives the firm additional incentive to collect customer information. Proposition 1 shows that when a firm creates superior customization value (α) at lower costs

(*c*), the firm collects more information (since the partial derivatives of the expression in Equation (9) with respect to α and *c* are positive and negative, respectively), raises the price and increases the profit in the process. (For details of comparative statics, see the proof of Proposition 1 in Appendix.) The optimal price is given in Equation (10). We observe that the optimal price is increasing with the relative value of customization, as the derivative of Equation (10) with respect to α is positive. Further, we see that a firm that creates a higher relative value of customization can not only extract a higher level of information from the customer, but also benefit more from cross-selling since it does not have to limit the cross-selling activity. We also note that the optimal extent of cross-selling is invariant to α (Equation 11). Although the amount of information being collected increases with α, the obtained information is cross-sold at the same rate (given that cross-selling is invariant to α).

The optimal level of cross-selling may decrease with the profitability of cross-selling activities. In specific, when $\dfrac{k}{g(k)}$ decreases with *k*, the optimal level of cross-sold information drops according to Equation (11). Hence, in addition to unit cross-selling profit *k*, a firm should pay attention to its customers' privacy concerns $g(k)$. Customer concerns may indeed dominate additional cross-selling profit opportunities, and a firm may have to reduce the extent of its cross-selling activities.

Depending on the nature of industry and the type of information collected, cross-selling may create significantly different information utilities. According to our model, there is a positive relationship between profitability of cross-selling (*k*) and customer privacy cost. However, the nature of this relationship can obviously differ. To illustrate the results, we consider three different functional forms for $g(k)$. A convex relationship $\left(g(k) = k^3\right)$ represents the case where higher levels of cross-selling increases privacy cost at an increasing rate. A

concave relationship $\left(g(k) = k^{1/3}\right)$ captures the incrementally decreasing rate, and a linear one $\left(g(k) = k\right)$ represents the constant rate of increasing privacy cost. The figures presented below illustrate the behavior of optimal profits as a function of the relative value of customization (Figure 1a) and the unit cross-selling profit (Figure 1b) for different functional forms for $g(k)$.

We observe that the profit is more sensitive to the unit cross-selling profit than the relative value of customization since the former affects profits directly. Also, the functional form of $g(k)$ has a more dramatic effect on the total profit when k rather than α is varied. In particular, Figure 1b shows that the total profit could be lower when $g(k)$ is a convex rather than a concave function of the unit cross-selling profit. These observations underscore the importance of striking a balance in cross-selling activities.

[Insert Figure 1 here.]

Next, we analyze the optimal level of cross-selling. As seen in Figure 2, the firm can maximize the extent of its cross-selling activities $\left(s^{*} = 1\right)$ even if cross-selling does not generate a significant revenue (k small).[3] The figure also shows that the optimal level of cross-selling could decrease even when such activities become increasingly profitable. Specifically, when consumers a significant privacy cost $\left(g(k) = k^{3}\right)$, an increase in k boosts revenues from cross-selling. Still, the firm finds it optimal to reduce the level of its cross-selling activity in order to limit its customers' privacy costs and thereby charge a higher price for its product. Note that it is the extent of cross-selling activities that decrease, not the amount of information being collected.

[Insert Figure 2 here.]

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[3] We obtain corner solutions when k is small and $g(k) = k^{3}$ and when k is large and $g(k) = k^{1/3}$. In both cases $s^{*} = 1$.

We observe that the demand decreases with the relative value of customization. This is because the partial derivate of the expression for demand (given in Equation 12) with respect to α is negative $\left(\dfrac{\partial D}{\partial \alpha} = -\dfrac{k^2}{4\alpha^2 g(k)} \right)$. In other words, an increase in the relative value of customization results in fewer privacy-concerned customers being served. The firm finds it profitable to focus on a limited set of customers because it can increase its profit while charging a higher price and benefiting from a higher level of cross-selling. Hence, the firm prefers to follow a niche strategy whereby it limits its market share and focuses on a select set of customers who have a high value for the customized product.

Proposition 2. *Improvements in customization technology (i.e., higher α) lead the firm to follow a niche marketing strategy and focus on consumers with a high value for the customized product.*

Proposition 2 demonstrates the effect of the relative value of customization and the unit cross-selling profit on the customer profile served by the firm. The firm serves the customers with a high value for the customized product (i.e., those with high θ), but the exact level of such value depends on the privacy sensitivity of the customers; more privacy-sensitive consumers need to value the customized product more in order to be served. Hence, a niche marketing strategy where the firm focuses on high-value customers works best when customization is relatively valuable. As customization technology improves (higher α) to provide more value to consumers, their willingness to pay increases, rendering privacy less of an issue in deciding whether to purchase the product. However, the firm prefers to charge a premium and focus on the customers with the highest value while serving a more limited market. Interestingly, the demand and the relative value of customization are negatively associated. As the value of the

customized product increases, the firm responds by collecting more information and raising its price at such a rate that its total demand actually drops.

As the cross-selling activities become more profitable (higher k), the firm caters to a broader range of customers, even though this results in serving more privacy-concerned customers as well as customers who have a limited value for the customized product. High unit cross-selling profit leads to an increased focus on information gathering, and the firm broadens its target market to the masses and profits by focusing on obtaining and sharing customer information. Of course, this can only work when customers are not very sensitive to information gathering and their privacy costs are relatively low.

Proposition 3. *When consumers' privacy costs are relatively low, increases in the unit cross-selling profit activities (i.e., higher k) lead the firm to pursue a mass marketing strategy where the firm serves a broader range of customers who may have lower valuations for the customized product.*

The firm may follow a mass marketing strategy when cross-selling is profitable. This outcome arises at optimality when the positive effect of cross-selling (through larger revenues) dominates its negative effect (through reduced customer valuations and price), which happens, for example, when $g(k)$ is a concave function of the unit cross-selling profit such that an increase in k does not cause too much concern on the part of consumers.

The results of Proposition 2 and 3 are illustrated in the figure below. For all values of α and all three functional forms of $g(k)$ being considered, as the relative value of customization increases, the firm becomes more of a niche marketer, as it focuses more on the most profitable customers. Figure 3a illustrates this result. The effect of the unit cross-selling profit on the total demand is mixed, however. As can be seen in Figure 3b, when consumers are not sensitive to

changes in the unit cross-selling profit $\left(g(k)=k^{1/3}\right)$, the firm's market may grow with k while the firm engages more and more in cross-selling. On the other hand, just the reverse is the case when consumers are indeed sensitive to changes in the unit cross-selling profit .

[Insert Figure 3 here.]

So far we have observed that a low customized product value (α) coupled with significant cross-selling opportunities render serving the broad market more profitable (Propositions 2 and 3). In information-intensive environments, prices may also decrease as a result of cross-selling. A profitable strategy may even call for charging a negative price (i.e., paying to the customers for their personal information). We find the optimal price in the model

to be $p^* = \dfrac{\left(2\alpha g(k)+k^2\right)^2\left(2\alpha g(k)-3k^2\right)}{128\alpha g(k)^3 c}$ (see Equation 10). Thus, when k is sufficiently high

$\left(k \geq \sqrt{\dfrac{2\alpha g(k)}{3}}\right)$, the firm provides its services free of charge or even compensates the customers

for participation.

Proposition 4. *Cross-selling strategies help the firms to lower prices and reach broader*

markets with free services when $\dfrac{3k^2}{2g(k)} > \alpha$.

Many firms offer free services and may even pay to the customers on the Internet. One of the motivations for distributing money is to motivate customers to visit the website so that the firm may obtain additional revenues through cross-selling. For example, firms may benefit from banner ads, click throughs as well as various other activities. Although the customers may not obtain significant direct value from the customized product, free offers and services may provide further incentives for participation.

We now turn our attention to welfare implications. In general, we find that the society benefits from the existence of information collection and sharing activities. However, the excessive use and exploitation of such activities may also reduce welfare.

Proposition 5. *Total surplus increases at a decreasing rate with the level of information collection until a certain threshold, beyond which total surplus decreases with the level of information collection.*

Some level of information collection increases the value of the product and correspondingly consumers' willingness to pay for it, and thus contributes to both profits and consumer surplus. On the other hand, extensive collection of personal information is too costly for the firm and detrimental to consumers' privacy. Total welfare therefore increases at a decreasing rate with information collection, but eventually decreases at excessive levels. Figure 4a illustrates this result for different unit cross-selling profit and information utility relationships as captured by $g(k)$.

We can also observe the affect of cross-selling on total surplus. Since cross-selling directly contributes to profits, it can increase total welfare, especially when consumers are relatively less sensitive to the firm's information usage practices. Even when this is not the case, some level of cross-selling can increase welfare because of the incentives it gives the firm to collect more information and thereby improve its product. Figure 4b illustrates this observation.

[Insert Figure 4 here.]

In general, we find that improvements in customization technology provide clear benefits to the society. Our comparative statics analysis of the consumer surplus (given in Equation 14) as well as the total surplus (see Equations 13 and 14) suggests that increasing α is associated with significant welfare enhancements.

Proposition 6. *A niche marketing strategy facilitated by improvements in customization technology (i.e., higher α) increases both consumer and total surplus.*

Interestingly, we find that serving fewer customers is also associated with increased consumer surplus and welfare. This is because the niche marketing strategy is justified for high α values, which benefit the firm as well as consumers (due to the increased value for the product) at such a level that the corresponding contribution to the consumer surplus by itself more than makes up for the loss due to serving fewer consumers.

V. DISCUSSION AND CONCLUSIONS

This study contributes to the privacy literature by analytically examining the optimal pricing, information collection and customization, and cross-selling strategies in the presence of privacy concerns. We characterize the optimal outcomes and analyze the firm strategies in this domain. Improvements in information technology coupled with superior targeting techniques increase cross-selling opportunities and help the firms benefit from additional sources of revenue. Interestingly, we find that a firm may need to limit its cross-selling activities as the unit cross-selling profit increases. Hence, the intricate relationship between cross-selling activities and the level of customer intimacy firms aim to reach warrants special consideration. Our results show that the optimal level of demand may decrease with the value of customization, which is contrary to what Syam and Kumar [28] suggest. Specifically, an increase in consumers' value for customization favors a niche marketing strategy, while an increase in the unit cross-selling profit may provide incentives for mass marketing. Our results suggest that a firm that emphasizes cross-selling and information sharing with third parties may need to follow a targeting strategy different from that of a firm that emphasizes the provision of superior individualized services. Also, cross-selling strategies may lower prices and provide significant strategic advantages due

to increased customer satisfaction and a broader market reach. Hence, we provide significant implications of cross-selling strategies on pricing and target market selection. Low levels of information collection increases total surplus, whereas high levels of information collection decreases it. Further, a niche marketing strategy facilitated by improvements in customization technology increases both consumer and total surplus. The increase in consumer surplus due to improvements in customization technology is in line with the findings of Dewan et al. [29] and Cavusoglu et al. [24]. The optimal outcomes discussed here can vary greatly depending on market characteristics, and therefore managers need to consider their particular market conditions before deciding on a course of action.

The potentially welfare-increasing effects of information collection and cross-selling provide implications on privacy regulation as well. For example, there are differences between the U.S. and European Union where law makers prefer to follow stricter rules and regulations. We do not find a clear result on whether governments should facilitate or limit information sharing practices; the optimal course of action depends on the level of consumers' privacy concerns, the profitability of cross-selling opportunities, and the level of information sharing that is taking place. In the past, the issues surrounding privacy and social welfare has led researchers to investigate the appropriate public policies and regulations, and we know that privacy regulation typically increases the cost of solicitation and information collection. Gould [30] demonstrated that privacy regulation could raise both social welfare and the total amount of information produced (strategically) by consumers. On the other hand, Fudenberg and Villas-Boas [31] argued that regulation may also lower social welfare in monopolistic as well as competitive settings, implying the ambiguity of the social value of privacy regulation. Akçura and Srinivasan [26] consider cross-market collection and sale of personal information in a setting

where consumers balance the benefit from consuming a personalized product against direct privacy costs, and find that legal regulations may improve firm profits. However, overly strict privacy regulations that prevent solicitations to consumers may not be optimal either [32]. Considering the positive effect information collection and cross-selling may have on social welfare in our setting, we maintain that privacy regulation should balance the interests of consumers and firms, and whenever feasible, the terms should be tailored to each industry [19].

Firms can easily offer personalized offers and sites online. Such customized offerings provide incentives to reveal more information and pay higher prices. There is evidence that once customers realize the benefits, companies can successfully charge higher prices [33]. Our results also indicate that when customer information is too much exploited and cross-selling activity is not carefully monitored, customers may not participate in the offerings, and consequently firm profits may drop.[4] Many firms such as Netzero that initially provided free services and tried to profit from customer information had to declare bankruptcy later on. When firms carefully monitor customer concerns, a mass marketing strategy helps the firms to better benefit from cross-selling and to survive in the market. For example, firms such as AOL, Google and Yahoo all successfully pursued mass marketing initially. Eventually, as customers better realize the value of customized offerings, niche marketing provides superior profits. Arguably, Google can offer superior matches for customer preferences, and it has recently introduced many niche services such as Google Scholar, Google Earth, Google Docs, Google Health, etc. In turn, such

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[4]Firms can easily exploit customer information once they decide to do so. There are many companies and information brokers such as www.caldwell-list.com, www.cash4lead.com, www.infousa.com that buy lists of customer information. In addition, member companies of direct marketing association www.the-dma.org can benefit from their member databases and easily search and find interested parties and brokers for the information they want to sell.
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niche segments provide even more information, enabling the firm to achieve customer intimacy with superior targeted products.

Successful firms can also overcome and limit cross-selling concerns and may increase their profits by serving a broader range of customers as cross-selling becomes more profitable. For example, Citibank invests a significant amount of money in its electronic banking technology, where it can better collect and use customer information to identify many products for cross-selling, including insurance, mortgage, credit, and investment services. While Citibank prefers to reach the mass market, some other banks (such as ING) prefer to target a niche segment while providing superior value via limited cross-selling.

Our model has certain limitations due to the nature of this work and the simplifications that have been made in trying to focus on salient aspects of the business problem. For example, contrary to our characterization, neither firms nor consumers may be able to accurately estimate privacy costs. In addition, consumers may behave strategically, and collected consumer information may be subject to further inaccuracies and uncertainties. The current model allows us to characterize the steady-state equilibrium in a complete information case. Future research may examine extensions that address some of these limitations.

Figure 1. Changes in profit is more sensitive to unit cross-selling profit (k) rather than relative value of customization (α)

(a) Sensitivity of total profit with respect to relative value of customization
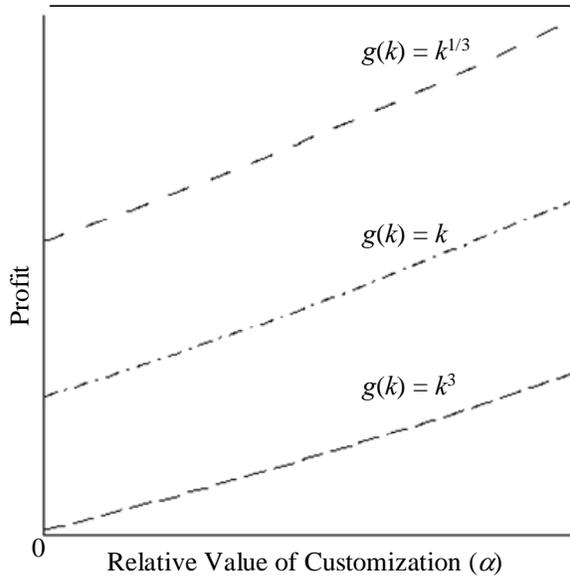
(b) Sensitivity of total profitability with respect to the unit cross-selling profit
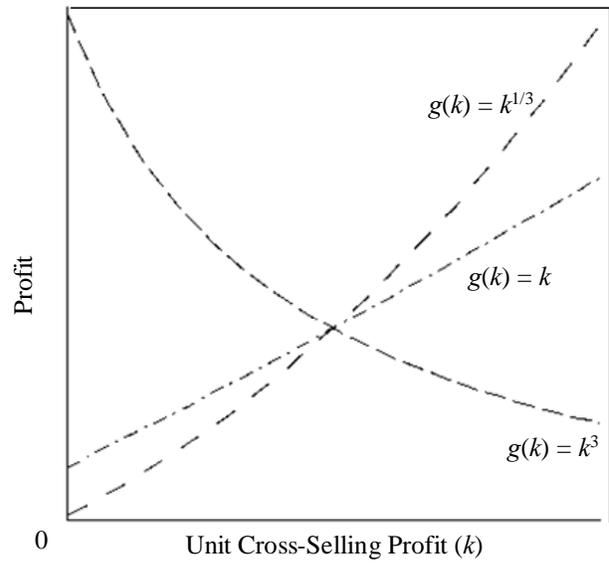
Figure 2. The optimal level of cross-selling as a function of the unit cross-selling profit
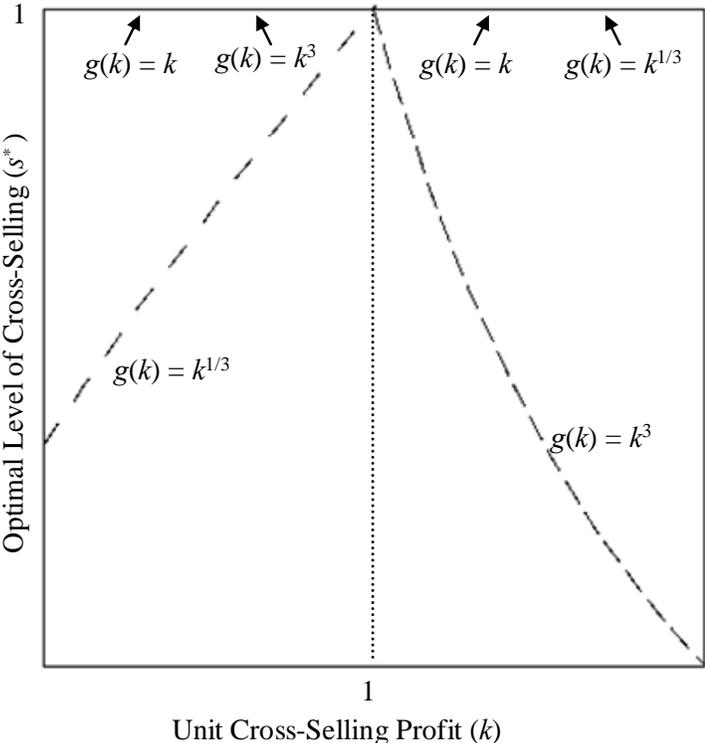
Figure 3. Demand as a function of relative value of customization and unit cross-selling profit

(a) Demand versus relative value of customization
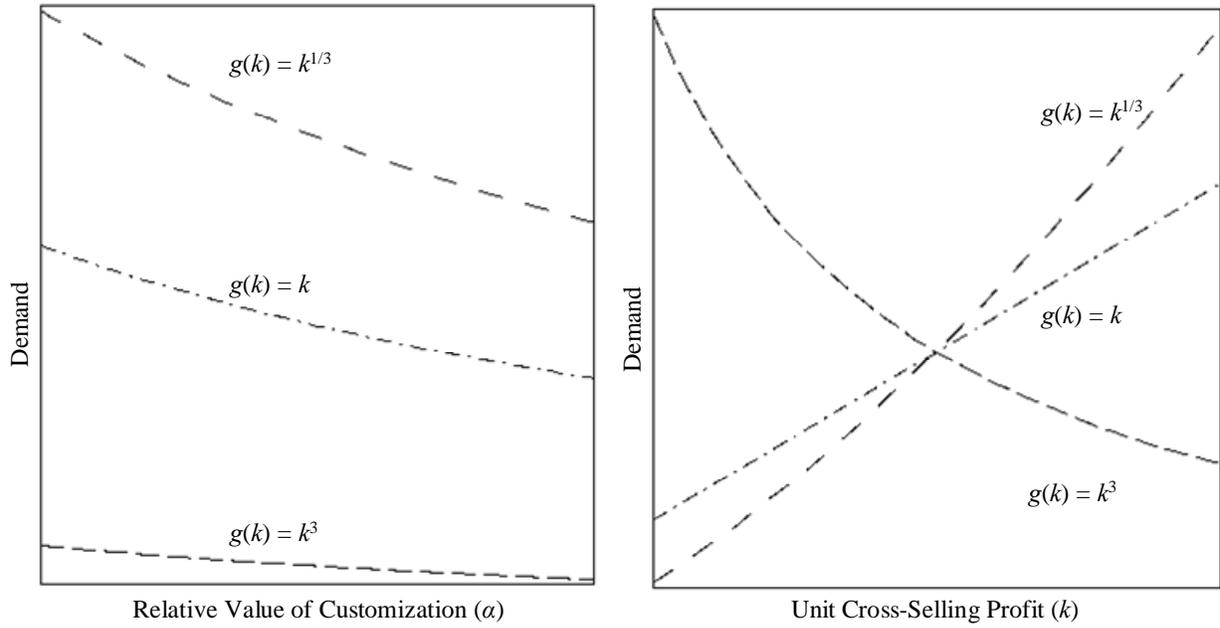
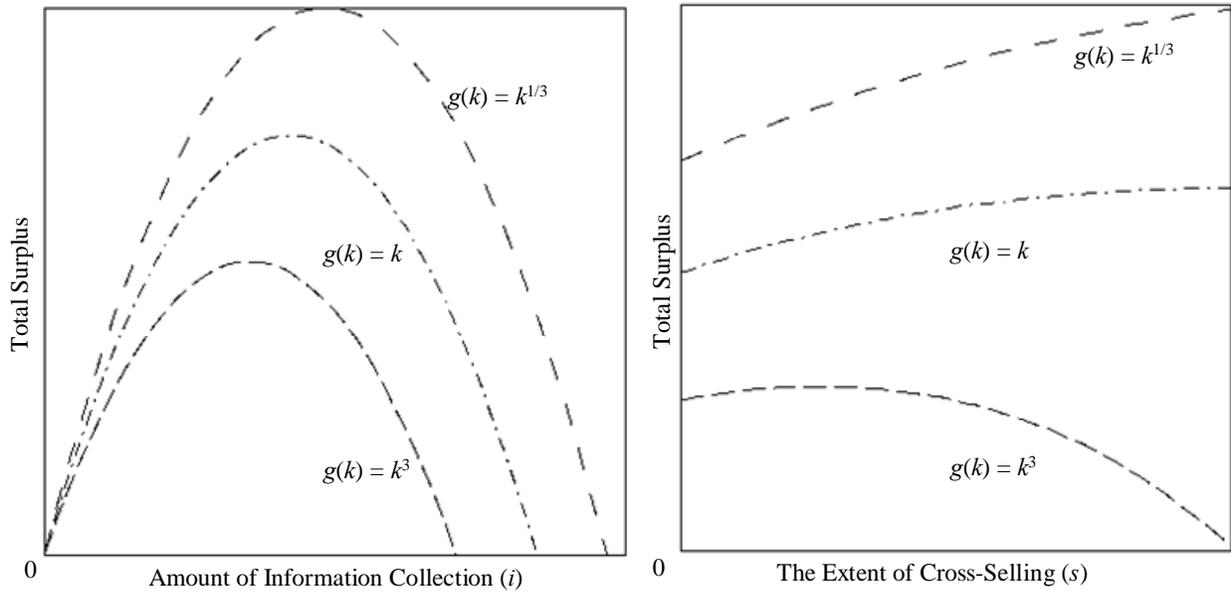(b) Demand versus unit cross-selling profit

Figure 4. Welfare effects of information collection and cross-selling

(a) Total surplus versus information collection

(b) Total surplus versus cross-selling

Appendix

Table 1. Notation

i	The level of information collection (and corresponding personalization)
s	The extent of the firm's cross-selling activity
k	Parameter for the unit cross-selling profit
c	Cost parameter (for information collection)
θ	The parameter for the value of personalization; $\theta \in [0,1]$
β	The parameter for the cost of privacy; $\beta \in [0,1]$
$g(k)$	The function that relates unit cross-selling profit to privacy costs
p	Price
D	Demand
Π	Profit
CS	Consumer surplus

The Solution of the Model and Proof of Proposition 1. We maximize the profit expression in equation (5) with respect to p, i and s. The profit-maximizing first-order conditions suggest that we have $\partial \Pi / \partial p = 0$, $\partial \Pi / \partial i = 0$ and $\partial \Pi / \partial s = 0$. Solving these three equations for three unknowns simultaneously, we obtain the optimal values as $i^* = \dfrac{\left(2\alpha g(k)^2 + k^2\right)^2}{32\alpha c g(k)^2}$,

$$p^* = \frac{\left(2\alpha g(k) + k^2\right)^2 \left(2\alpha g(k) - 3k^2\right)}{128 \alpha g(k)^3 c}, \quad s^* = \frac{k}{g(k)} \quad \text{with} \quad D^* = \frac{1}{2} + \frac{k^2}{4\alpha g(k)} \quad \text{and} \quad \Pi^* = \frac{\left(2\alpha g(k) + k^2\right)^4}{1024 c \alpha^2 g(k)^4}.$$

After checking the determinants of the Hessian, we see that the second order conditions are

satisfied since $\frac{\partial^2 \Pi}{\partial p^2} = -\frac{64g(k)^2 c}{\left(k^2 + 2g(k)\alpha\right)^2} < 0$, $\frac{\partial^2 \Pi}{\partial p^2} \cdot \frac{\partial^2 \Pi}{\partial i^2} - \frac{\partial \Pi}{\partial p\partial i} \cdot \frac{\partial \Pi}{\partial i\partial p} = \frac{128g(k)^2 c^2}{\left(k^2 + 2g(k)\alpha\right)^2} > 0$, and

$$\frac{\partial^2 \Pi}{\partial s^2}\left(\frac{\partial^2 \Pi}{\partial p^2} \cdot \frac{\partial^2 \Pi}{\partial i^2} - \frac{\partial \Pi}{\partial p\partial i} \cdot \frac{\partial \Pi}{\partial i\partial p}\right) - \frac{\partial \Pi}{\partial s\partial i}\left(\frac{\partial \Pi}{\partial i\partial s} \cdot \frac{\partial^2 \Pi}{\partial p^2} - \frac{\partial \Pi}{\partial p\partial l} \cdot \frac{\partial \Pi}{\partial i\partial p}\right) + \frac{\partial \Pi}{\partial s\partial p}\left(\frac{\partial \Pi}{\partial i\partial s} \cdot \frac{\partial \Pi}{\partial p\partial i} - \frac{\partial \Pi}{\partial p\partial l} \cdot \frac{\partial^2 \Pi}{\partial i^2}\right)$$

$= -\frac{\left(k^2 + 2g(k)\alpha\right)c}{\alpha^2} < 0$. Note that the above internal solutions are valid when $1 > \frac{k}{g(k)} > \underline{s}$.

However, s can be greater than one or less than $\underline{s}$ according to this specification, which should

not be allowed based on the definition of the variable. Thus, we say $s^* = \min\left\{\frac{k}{g(k)}, 1\right\}$ when

$\frac{k}{g(k)} > \underline{s}$. Hence, s^* can be constrained at a boundary solution such as 1 or $\underline{s}$. In order to find

the solution when s is constrained at a boundary value, we simultaneously solve $\partial \Pi / \partial p = 0$ and

$\partial \Pi / \partial i = 0$, and find the value of p and i as a function of s. This provides us with

$i^* = \frac{\left(2\alpha - s^{*2}g(k) + 2ks^*\right)^2}{32\alpha c}$ and $p^* = \frac{\left(\left(2\alpha - s^{*2}g(k)\right)^2 - 4k^2 s^{*2}\right)^2}{128\alpha c}$. We also obtain

$D^* = \frac{1}{2} - \frac{s^{*2}g(k) - 2ks^*}{4\alpha}$ and $\Pi^* = \frac{\left(2\alpha - s^{*2}g(k) + 2ks^*\right)^4}{1024c\alpha^2}$. The corresponding demand should be

$1 > D > 0$. Using the optimal values, we have $D^* = \frac{1}{2} - \frac{s^{*2}g(k) - 2ks^*}{4\alpha}$. Hence, $1 > D > 0$

requires $\alpha > \left|\frac{s^{*2}g(k) - 2ks^*}{2}\right|$, or using the optimal values for an internal solution, we have

$\alpha > \frac{k^2}{2g(k)}$. Hence, sufficiently high α such that $\alpha > \frac{k^2}{2g(k)}$ provides a downward sloping

demand curve that ensures customer participation, that is, the demand increases as price drops.

When $\dfrac{k}{g(k)} < \underline{s}$, the firm either does not engage in cross-selling or has to engage in a

minimum of cross-selling level by setting s to $\underline{s}$. When we set s^* to zero, we obtain

$\Pi^*(s=0) = \dfrac{\alpha^2}{64c}$. This is equivalent to the firm offering a personalized product and using

customers' personal information only for providing customized offerings with no additional

cross-selling. In this case, the firm collects information $i^*(s=0) = \dfrac{\alpha}{8c} > 0$ and charges a price of

$p^*(s=0) = \dfrac{\alpha^3}{8c}$ in the absence of cross-selling. On the other hand, we find the optimal profit as

$\Pi^*(s=\underline{s}) = \dfrac{\left(2\alpha - \underline{s}^2 g(k) + 2k\underline{s}\right)^4}{1024c\alpha^2}$. $\Pi^*(s=0) > \Pi^*(s=\underline{s})$ if   and   only   if

$\dfrac{\alpha^2}{64c} > \dfrac{\left(2\alpha - \underline{s}^2 g(k) + 2k\underline{s}\right)^4}{1024c\alpha^2}$. But, given a sufficiently small $\underline{s}$ such that $\underline{s} < \dfrac{2k}{g(k)}$, we see that

the firm profits more with cross-selling.

We find that the optimal price, profit, and the level of information collection increase

with the relative value of customization (α). The extent of cross-selling is invariant to α. The

optimal level of cross-selling may decrease with the unit cross-selling profit activities in the

industry. Partial derivatives of the optimal price, profit, and the level of information collection

with respect to α are the following.

$$\dfrac{\partial p^*}{\partial \alpha} = \dfrac{\left(2\alpha g(k) + k^2\right)\left(8\alpha^2 g(k)^2 - 6\alpha k^2 g(k) + 3k^4\right)}{128c\alpha^2 g(k)^3}$$

$$\dfrac{\partial \Pi^*}{\partial \alpha} = \dfrac{\left(2\alpha g(k) - k^2\right)\left(2\alpha g(k) + k^2\right)^3}{512c\alpha^3 g(k)^4}$$

$$\frac{\partial i^*}{\partial \alpha} = \frac{\left(2\alpha g(k) - k^2\right)\left(2\alpha g(k) + k^2\right)}{32c\alpha^2 g(k)^2}$$

All of these expressions are positive given $\alpha > \dfrac{k^2}{2g(k)}$. The extent of cross-selling is invariant to

the relative value of customization since $\dfrac{\partial s^*}{\partial \alpha} = 0$. Given $s^* = \dfrac{k}{g(k)}$, a convex function for $g(k)$

such as $g(k) = k^2$ satisfies $\dfrac{\partial s^*}{\partial k} < 0$, and thus the optimal extent of cross-selling can possibly

decrease with the profitability of such sale.

Proof of Proposition 2. Given the demand $D^* = \dfrac{1}{2} + \dfrac{k^2}{4\alpha g(k)}$, we have $\dfrac{\partial D}{\partial \alpha} = -\dfrac{k^2}{4\alpha^2 g(k)} < 0$,

indicating that total demand decreases with α. To see how different customer segments are

affected by α, we first derive the θ value for the consumers who are indifferent to purchasing

the product (i.e., $\underline{\theta}$). Given the optimal conditions, we obtain $\underline{\theta} = \dfrac{4\beta k^2 - 3k^2 + 2\alpha g(k)}{4\alpha g(k)}$. In

other words, the slope of the line in the (θ, β) unit square that identifies the indifferent

consumers is $\dfrac{k^2}{\alpha g(k)}$. Said differently, the $\underline{\theta}$ value for consumers who are the least concerned

about privacy $(\beta = 0)$ is $\dfrac{k^2}{\alpha g(k)}$ less than that for those who are the most concerned $(\beta = 1)$.

Looking at the partial derivative, we see that the improvements in product customization results

in fewer privacy-concerned customers being served, and the firm focuses more on the higher

valuing customers.

Proof of Proposition 3. Given $D^* = \dfrac{1}{2} + \dfrac{k^2}{4\alpha g(k)}$, we have $\dfrac{\partial D}{\partial k} = \dfrac{k\left(2g(k) - kg'(k)\right)}{4\alpha g(k)^2}$, where

$g'(k)$ is the derivative of $g(k)$ with respect to k. That is, the demand is increasing in k if and

only if $g(k)/g'(k) > k/2$. A concave function of k such as $g(k) = k^{1/3}$ satisfies this condition.

Recall that $\underline{\theta} = \dfrac{4\beta k^2 - 3k^2 + 2\alpha g(k)}{4\alpha g(k)}$, and that the slope of $\underline{\theta}$ in the (θ, β) unit square

identifies the indifferent consumers. Note also that a negative change in this slope is associated

with more privacy-concerned customers purchasing the product relative to those not concerned.

By taking the partial derivative of this slope with respect to k, we find that a higher k makes it

profitable for the firm to serve more privacy concerned customers with lower valuations,

providing $g(k)/g'(k) > k/2$. Again, $g(k) = k^{1/3}$ satisfies this condition.

Proof of Proposition 4. This follows from Propositions 3 and 4 and given

$p^* = \dfrac{\left(2\alpha g(k) + k^2\right)^2 \left(2\alpha g(k) - 3k^2\right)}{128\alpha g(k)^3 c}$ (see Equation 10). The expression for the optimal price

suggests that $p^* \le 0$ if and only if $\alpha \le \dfrac{3k^2}{2g(k)}$. Also, there exists a region where $\alpha \le \dfrac{3k^2}{2g(k)}$.

But since $\dfrac{3k^2}{2g(k)} > \dfrac{k^2}{2g(k)}$, $p^* \le 0$ for α sufficiently small such that $\dfrac{3k^2}{2g(k)} \ge \alpha > \dfrac{k^2}{2g(k)}$.

Proof of Proposition 5. Total surplus is the sum of profit and consumer surplus. To find the

partial derivative of total surplus with respect to the amount of information collection, we first

need to derive total surplus as a function of i. The profit as a function of i and s is given in

proof of Proposition 1 as $\Pi(i, s) = \dfrac{i\left(2\alpha + 2ks - (s)^2 g(k)\right)^2}{16\alpha} - ci^2$. We derive consumer surplus as

a function of i and s as

$$CS(i,s) = \int_0^1 \int_\theta^1 \left(\theta i\alpha - \beta s^2 ig(k) - p\right) d\theta\, d\beta$$

$$= \frac{i\left(7s^4 g(k)^2 - 12s^2 g(k)\alpha - 12s^3 g(k)k + 12\alpha^2 + 24\alpha ks + 12k^2 s^2\right)}{96\alpha}.$$

The sum of $\Pi(i,s)$ and $CS(i,s)$ gives total surplus (TS) as a function of i and s. Plugging in the optimal s^* given in equation (5) and differentiating with respect to i, we find (after simplification): $\dfrac{\partial TS}{\partial i} = \dfrac{13k^4 + 36k^2\alpha g(k) + 36\alpha^2 g(k)^2 - 192c\alpha g(k)^2 i}{96\alpha g(k)^2}$ and $\dfrac{\partial^2 TS}{\partial i^2} = -2c$. Thus, total surplus increases with the amount of information collection (at a decreasing rate) for

$i < \dfrac{13k^4 + 36k^2\alpha g(k) + 36\alpha^2 g(k)^2}{192c\alpha g(k)^2}$ and decreases otherwise.

Proof of Proposition 6. Consumer and total surplus equal

$$CS = \frac{\left(2\alpha g(k) + k^2\right)^2 \left(12\alpha^2 g(k)^2 + 12k^2\alpha g(k) + 7k^4\right)}{3072c\alpha^2 g(k)^4} \text{ and}$$

$$TS = \frac{\left(2\alpha g(k) + k^2\right)^2 \left(12\alpha^2 g(k)^2 + 12k^2\alpha g(k) + 5k^4\right)}{1536c\alpha^2 g(k)^4}, \text{ respectively.}$$

Partial derivatives of these expressions with respect to α equal (after some simplification)

$$\frac{\partial CS}{\partial \alpha} = \frac{\left(2\alpha g(k) + k^2\right)^2 \left(12\alpha^2 g(k)^2 k^2 - 6\alpha g(k)k^4 + 24\alpha^3 g(k)^3 - 7k^6\right)}{1536c\alpha^3 g(k)^3}$$

$$\frac{\partial TS}{\partial \alpha} = \frac{\left(2\alpha g(k) + k^2\right)^2 \left(12\alpha^2 g(k)^2 k^2 - 6\alpha g(k)k^4 + 24\alpha^3 g(k)^3 - 5k^6\right)}{1536c\alpha^3 g(k)^3}$$

Both of these expressions are positive if and only if $12\alpha^2 g(k)^2 k^2 - 6\alpha g(k)k^4 + 24\alpha^3 g(k)^3$

$-7k^6 > 0$. Alternatively, $12\alpha^2 \dfrac{k^2}{g(k)} - 6\alpha \dfrac{k^4}{g(k)^2} + 24\alpha^3 - 7\dfrac{k^6}{g(k)^3} > 0$ holds given a high α.

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