An economic analysis of internet privacy regulation[1]

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August 2015

[1] I thank the George Mason Law and Economics Center for financial support and helpful comments. I also thank conference participants at the Association for Private Enterprise Education and George Mason University for comments.

Abstract

This paper analyzes the rationale for regulation of privacy in two new models of why firms collect consumer information. Prior work has focused on the use of consumer information for price discrimination. In this paper, I consider two different rationales. In the product improvement model, I assume that collecting consumer information allows firms to improve their product. In the supplemental good model, I assume that collecting consumer information allows firms to know which of two additional goods a consumer values. I show that in both models firms tend to offer too much, rather than too little, privacy protection from the point of view of maximizing consumer welfare. In both models, privacy protections soften the competition between firms and lead to higher prices.

1 Introduction

Online platforms such as Google and Amazon store collect huge amounts of personal information about consumers that visit and use their websites. According to a recent survey, more than 90 percent of people viewing controlling access to their personal information very important, but over 50 percent felt they had little control of this data (Goel 2015). Concerns about the privacy of this type of consumer information have led to increasing calls for more stringent privacy regulations for online platforms. The US Federal Trade Commission recently warned that such regulation was likely unless firms make their privacy policies more prominent, easier to understand, and clearly explain how users can opt-out of providing personal information.

While concerns about privacy and the collection of consumer information are becoming ubiquitous, they are raised in a fashion that is puzzling to an economist. That is, they typically do not explain what potential market failures may exist that would lead the market not to provide the optimal amount of privacy when consumers use internet services such as search engines or shopping platforms. This paper models firms incentive to collect consumer information in a Hotelling duopoly model to explore what, if any, market failures may exist, whether there are any clear conditions under which firms will tend to supply too little or too much privacy, and to examine whether there is any role for government regulation to correct those market failures.

In this paper, I will consider two different motivations that firms may have to collect consumer information. First, firms might find that collecting consumer information helps them to improve their products. That is, collecting consumer information might enable firms to learn more about what features of their products or their product delivery systems consumers value, enabling them to make changes that make their products more valuable to all consumers. (See Goldfarb and Tucker (2012) for a more detailed explanation of how collecting consumer information drives innovation.) I capture this movitivation in a two-period product improvement model in which the value of a firm's second period product value is increasing in its first period market share if it collects consumer information in the first period. If the firm does not collect this consumer information (it protects consumer privacy), however, then its product value remains the same in the second period. In this model, some consumers value privacy. So, a firm that protects privacy has an advantage in selling to these consumers.

Second, by collecting consumer information, firms might be better able to tailor their product offerings to the idiosyncratic preferences of any given consumer.

I capture this motivation in a supplemental offering model in which each firm can choose to offer one, and only one, additional good along with the primary good. One can think of this as being due to limited consumer attention and limited space on a web page. For example, if a consumer visits a web page to buy one good, the seller can list another good on the page to recommend as well, but if it lists too many other goods, the recommendation loses value. If a firm collects consumer information, then it knows which of two possible supplemental goods a consumer values and can always offer every consumer the supplemental good it values. If a firm protects privacy (so it does not collect consumer information), then it must make a supplemental good offer without knowing precisely which good any given consumer values.

I find that in both models, firms have an excessive incentive to protect privacy relative to what would maximize consumer welfare. The main reason is that protecting privacy softens competition. In the product improvement model, a firm that protects privacy commits to caring less about its first period market share. This gives it a reduced incentive to cut prices in period 1. Because prices are strategic complements, this leads the other firm to charge higher prices as well (whether or not it protects privacy). As a result, in equilibrium, at least one firm will always protect privacy (even if consumers value privacy very little). If consumers do not value privacy much, this equilibrium will lead to lower consumer welfare than if neither protected privacy. Similarly, if consumers value privacy just enough so that in equilibrium both firms protect privacy, consumer welfare would be larger if at least one firm did not protect privacy.

In the supplemental good model, if one firm is uncertain about which product a consumer values, then, with positivie probabilitty, the other firm will not face competition for its supplemental offering. This causes that firm to charge a higher price, which, in turn, benefits the other firm. On the other hand, a firm that collects consumer information will always offer each consumer the product she value most. The combination of these effects tend to encourage an equilibrium in which one firm protects privacy while the other does not. The competition softening benefit of protecting privacy, however, make consumers worse off, both because they have to pay higher prices and because they may not have their desired product available. Thus, the results of both models cast doubt on the rationale for minimum privacy regulations given that they suggest the likely market failure (at least in these models) is in the direction of too much privacy protection rather than too little. It is worth noting that each of these results hold independently of the exogenous degree of product differentiation between the two firms, as measured by the transport cost parameter.

The economics of privacy literature began with Stigler (1980) and Posner (1981). More recently, there are a number of papers that model privacy in the context of information revelation about a trading partner's type that can affect the level of surplus the transaction generates. Hermalin and Katz (2006) examine the efficiency effects of information revelation about types in terms of its effect of pooling or separating equilibria. They show that increased information revelation can sometimes improve and sometimes decrease efficiency. Calzolari and Pavan (2006) model the affects of privacy in a common-agency setting. Burke et al. (2012) show that firms collect excessive information about consumer types in an adverse selection model.

Almost all the recent economics literature about the collection of consumer information focuses on price discrimination. Taylor (2004) examines the welfare effect of the sale of consumer information for price discrimination purposes in a monopoly model. Conitzer et al. (2012) analyze the welfare effect of costly privacy which can prevent a monopolist from price discriminating. Shy and Stenbacka (2014) analyze the use of firm collection of consumer information for price discrimination in a competition setting. They find that allowing firms to use information about their own consumers to price discriminate increases firm profits but decreases welfare. Taylor and Wagman (2014) examine the use of consumer information for price discrimination across several different oligopoly models and find that the welfare effects vary depending on the model.[1] Zhang (2010) analyzes the competitive effect of product personalization in a setting without exogenous product differentiation or consumer privacy preferences. Because his model is one of product personalization based on individual purchase history rather than on statistical learning based on acquiring a pool of consumer information, he does not consider a firm's ability to choose not to acquire consumer information. As Spulber (2009) notes, online platforms often acquire consumer information even from consumers that do not purchase from them. Fudenberg and Villas-Boas (2006) provide an excellent survey of the behavior-based price discrimination literature. Hui and Png (2006) provide a nice survey of the economics of privacy literature.

Casadesus-Masanell and Hervas-Drane (2014) model the effect of consumer information on product quality. Their approach is very different from the one in this paper. They model a setting in which consumers derive positive value from providing information to firms (it makes the particular consumer value the

[1] Corts (1998) was one of the first to examine price discrimination in a competitive setting and show it can improve consumer welfare.

product more, though it does not make it more valuable to other consumers), but the value of the product decreases in the firm's disclosure of that information (the consumers do not like the advertising that disclosure generates). They find that consumers benefit from competition primarily through lower prices, not less disclosure. de Corniere and Nijs (2014) model the impact of disclosure of consumer information by an adertising platform. Campbell et al. (2015) present a complementary model of how privacy regulation might impair competition. In their setting,privacy regulation imposes a fixed cost, thus can disadvantaged niche entrants against generalized incumbents. Evans (2009) provides an overview of the online advertising industry.

The next section analyzes the product improvement model. Section three analyzes the supplemental good model. Section four concludes.

2 Product improvement model

Because most calls for privacy regulation are targeted at large firms with only a small number of competitiors, such as Google or Amazon, I will use a model of Hotelling competition that allows for varying degrees of market power. Firm 0 and firm 1 will be located at opposite ends of a line of length one. Consumers are uniformly distributed along this line. Each firm offers one good, and consumers' base value for this good from firm $i \in \{0, 1\}$ is v^i. There is zero marginal cost of production.

A consumer's location on the line also re□ects her preference for one firm or the other, so that the net value for a consumer located at point $x \in [0, 1]$ of buying from firm 0 is $v^0 - tx$. Her net value from buying from firm 1 is $v^1 - t(1 - x)$.

In period 0, each firm also decides whether to collect consumer information or not. Collecting information helps improve a firm's platform which increases the value it can provide to consumers. To capture this, there are two periods of sales in the model, where in the second period the value of buying all goods from a particular firm increase by an amount that depends on the number of consumers the firm collected information from in the first period. That is, if a firm collects consumer information in period 1 and has market share m, then all its products in period 2 increase in value to consumers by $ztm \geq 0$. That is, z measures, in units of the transportation cost, the extent to which collecting consumer information enables a firm to improve its product. If a firm does not collect consumer information, then its value remains the same as in period 1. For simplicity, I assume no discounting.

To capture the fact that consumer's value privacy, I will assume that some consumers obtain a benefit of L if they purchase from a firm that protects their privacy. I will also assume that each firm must have only one privacy policy for all consumers. I make this assumption because it may be technologically difficult to have different systems for information collection, and because consumers may not believe that a firm that collects information from some consumers is honoring their request not to collect this information from them. I will operationalize this by assuming that a fraction q_p of consumers value privacy. Other consumers have no preference related to a firm's privacy policy.[2]

In this model, if the firms do not protect privacy in the first period, then they will compete very aggressively for consumers to improve their second period competitive position. This dynamic will lead to lower prices in the first period. On the other hand, if one firm offers privacy protection, it will capture more of the consumers who care about privacy but will be at a competitive disadvantage in the second period.

2.1 Period 2 equilibrium

In order to solve this model, I start by analyzing the period 2 pricing equilibrium when the firms have the same privacy policy and when they have different privacy policies. If both firms have the same privacy policies, then consumers chose which firm to buy from based only on their location, the prices, and the period 2 values of each product (which may depend on the period 1 market shares if the firms did not protect privacy). Let v_2^i be firm i's product value in period 2 taking into account any product improvement from period 1. This equilibrium is a standard Hotelling equilibrium in which prices and profits are:

$$p_2^{i,s} = t + (v_2^i - v_2^{-i})/3; \pi_2^{i,s} = \frac{(3t + v_2^i - v_2^{-i})^2}{18t}$$

If one firm protected privacy in period 1 (say, firm 0) and one did not (firm 1), then firm 0's product is more attractive to the fraction q_p of consumers that value privacy by L. Thus, the indifferent consumer who values privacy is located at $\frac{1}{2} + \frac{L+p_2^1-p_2^0+v_2^0-v_2^1}{2t}$. The indifferent consumer who does not value privacy is

[2] In a previous version of the paper, I also assumed that firm that collects consumer information can determine, in period 2, whether a consumer values privacy or not. As a result, it could charge different prices to privacy valuing consumers and consumers who do not value privacy in period 2. The results were qualitatively similar.

located at $\frac{1}{2}+\frac{p_2^1-p_2^0+v_2^0-v_2^1}{2t}$. The firms' period 2 profit functions are:

$$\begin{aligned}\pi_2^0 &= p_2^0\{q_p(\frac{1}{2}+\frac{L+p_2^1-p_2^0+v_2^0-v_2^1}{2t})+(1-q_p)(\frac{1}{2}+\frac{p_2^1-p_2^0+v_2^0-v_2^1}{2t})\} \quad (1)\\ \pi_2^1 &= q_p p_p^1(\frac{1}{2}-\frac{L+p_2^1-p_2^0+v_2^0-v_2^1}{2t})+(1-q_p)p_n^1(\frac{1}{2}-\frac{p_2^1-p_2^0+v_2^0-v_2^1}{2t})\end{aligned}$$

Differentiating these with respect to prices and setting them equal to zero yields the following equilibrium prices:

$$p_2^0=t+(q_pL+v_2^0-v_2^1)/3; p_2^1=t-(q_pL+v_2^0-v_2^1)/3$$

These can then be used in (1) to generate equilibrium period 2 profits as a function of period 2 product values:

$$\pi_2^{0,d}=\frac{(3t+q_pL+v_2^0-v_2^1)^2}{18t}; \pi_2^{1,d}=\frac{(3t+v_2^1-q_pL-v_2^0)^2}{18t}$$

2.2 Period 1 equilibrium

We can now use the period 2 profit functions to solve for the period 1 equilibrium (because if at least one firm collects consumer information, first period market share affects second period product values) . We do this for the three different privacy configurations. In this analysis, it is often convenient to express both the initial product values and the value for privacy in units of the transportation cost. Thus, we let $\tilde{L}=L/t$ and $\Delta\tilde{v}^i=(v^i-v^{-i})/t$

2.2.1 Both firms offer privacy

This is the simplest case. The firms play independent Hotelling games each period. So combined profits are just $\pi^{i,p}=\frac{(3t+v^i-v^{-i})^2}{9t}=t\frac{(3+\Delta\tilde{v}^i)^2}{9}$. Prices in each period are $p^{i,p}=t(1+\Delta\tilde{v}^i/3)$. Because neither firm is collecting consumer information, neither firm has an incentive to reduce its first period price to either improve its own competitive position or reduce the rival's ability to improve its competitive position.

2.2.2 Neither firm offers privacy

This is a standard Hotelling game with the twist that the second period values depend on the first period market share. So each firm's total profit function is:

$$\begin{aligned}\pi^{i,n} &= p^i(\frac{1}{2} + \frac{p^{-i} - p^i + v^i - v^{-i}}{2t}) + \frac{(3t + v_2^i - v_2^{-i})^2}{18t} \text{ with} \\ v_2^i - v_2^{-i} &= \Delta\frac{p^{-i} - p^i + v^i - v^{-i}}{t} = z(p^{-i} - p^i + \Delta\tilde{v}^i)\end{aligned}$$

Because first period market share increases second period value, both firms have an extra incentive to price aggressively in the first period. Thus, equilibrium prices are:

$$p^{i,n} = t[(1 - 2z/3) + \Delta\tilde{v}^i(9 - 2z - 2z^2)/(27 - 4z^2)]$$

If one compares $p^{i,n}$ with $p^{i,p}$, one can see that they are equal if $z = 0$ (first period market share does not affect second period product value). $p^{i,n}$ is also decreasing in z for all parameters that ensure both firms have positive market share and prices are non-negative.[3] The incentive to improve one's own product and deny one's rival the information to improve its product induces both firms to charge lower prices than they would if neither collected consumer information, and this effect is larger the larger is the future benefit from larger current market share.

In order to ensure that prices are positive and neither firm has negative market-share, I assume that $z < 3/2$ and $\Delta\tilde{v}^i$ is not too far from zero. $z < 3/2$ also guarantees that p^i is always increasing in $\Delta\tilde{v}^i$. Combined equilibrium profits for both periods with these prices are:

$$\pi^{i,n} = t[(1 - z/3) + \frac{\Delta\tilde{v}^i(3 - z)(18 + 7z)}{3(27 - 4z^2)} + \frac{(\Delta\tilde{v}^i)^2(162 + 72z - 17z^2 - 8z^3)}{2(27 - 4z^2)^2}]$$

2.2.3 One firm (firm 0) protects privacy

Using the second period profit functions and the fact that only firm 1 can improve its product's value, firm 0's overall profit function (its profit over both periods) is as follows:

$$\begin{aligned}\pi^0 &= p^0(\frac{1}{2} + (1 - q_p)\frac{p^1 - p^0 + v^0 - v^1}{2t} + q_p\frac{p^1 - p^0 + v^0 + L - v^1}{2t}) \\ &\quad + \frac{(3t + q_pL + v_2^0 - v_2^1)^2}{18t}\end{aligned}$$

[3] $\frac{dp^{i,n}}{dz} = -(\frac{2}{3} + \frac{2\Delta\tilde{v}^i(27-9z+4z^2)}{(27-4z^2)^2})$. This is negative whenever $\Delta\tilde{v}^i > -3$ and $z < 3/2$, which are necessary conditions for both firms to have positive sales.

The first line is its profit from sales in period 1. Its first period sales differ from half the market based on how its price and product value compares to its rival's (and its product value is greater by L fot those consumers who value privacy). The second line is its equilibrium profit in period 2 as a function of the period 2 product values, which depend on period 1 market share, $v_2^1 - v_2^0 = v^1 - v^0 + z(p^0 - p^1 - q_p L + t + v^1 - v^0)/2$.

Firm 1's overall profit function takes a very similar form:

$$\begin{aligned}\pi^1 &= p^1(\frac{1}{2} + (1-q_p)\frac{p^0 - p^1 + v^1 - v^0}{2t} + q_p\frac{p^0 - p^1 + v^1 - v^0 - L}{2t}) \\ &\quad + \frac{(3t + v_2^1 - v_2^0 - q_p L)^2}{18t}\end{aligned}$$

By differentiating the overall profit functions for both firms and setting the first order conditions equal to zero, we can solve for equilibrium prices. These equilibrium prices are:

$$\begin{aligned}p^0 &= t\frac{(162 - 54z - 3z^2 + 2z^3) + 3(q_p\tilde{L} + \Delta\tilde{v}^0)(18 - 2z - z^2)}{6(27 - z^2)} \\ p^1 &= t\frac{(162 - 54z - 9z^2 + 2z^3) + 3(\Delta\tilde{v}^1 - q_p\tilde{L})(18 - 2z - z^2)}{6(27 - z^2)}\end{aligned}$$

Again, p^0 and p^1 both equal $p^{i,n}$ and $p^{i,p}$ if $z = 0$. Both are also decreasing in z for all parameters that ensure both firms have positive market share and prices are non-negative. Again, this reflects the incentive to steal market-share in period 1 because of its effect on the period 2 competition. One can show that p^0 and p^1 do not decrease as quickly in z as does $p^{i,n}$ because period 1 market share has a greater effect on the period 2 competition when both firms collect consumer information than when only one does. One can then plug these equilibrium prices into the profit functions to obtain the equilibriumm profit for firms 0 and 1 when only firm 0 protects privacy. These expressions are omitted.

2.3 Period 0 equilibrium and welfare results

By comparing the profit of each firm in the three different period 1 configurations, one can determine under what conditions each of these configurations is an equilibrium. Neither firm protecting privacy is an equilibrium if a firm's profit is lower when only it protects privacy than if neither firm does. Both firms protecting privacy is an equilibrium if a firm's profit is lower when only the other firm protects privacy than if both do. There is an asymmetric equilibrium in which only one firm protects privacy if the privacy protecting firm would have lower profits in the equilibrium in which neither firm protects privacy, and the firm collecting information would have lower profits in the equilibrium in which both firms protect privacy.

Using the equilibrium prices under each configuration, one can compare aggregate consumer welfare across the three configurations for various parameter values. The following proposition shows that the privacy choices of the firms will not result in an equilibrium that maximizes consumer welfare if consumers do not value privacy very much because at least one firm will protect privacy even though consumers would be better off if neither did.

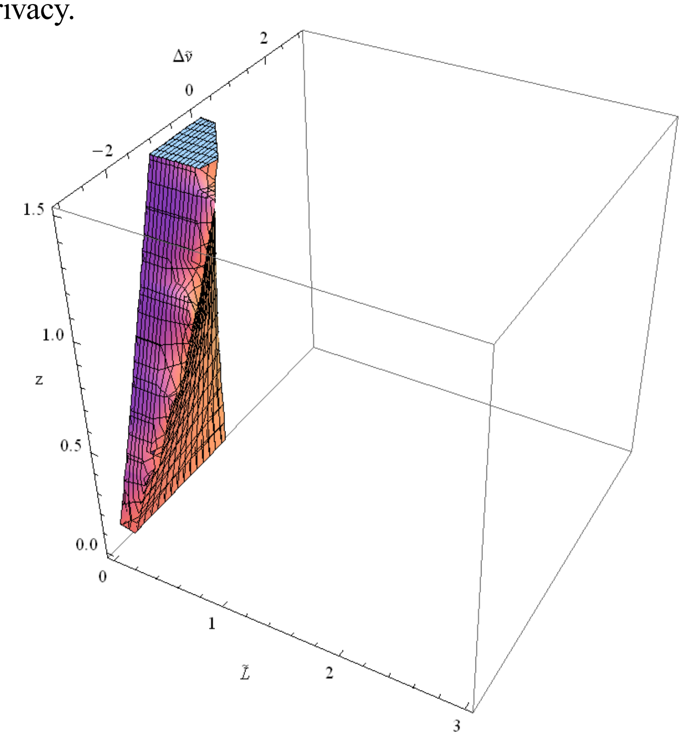
Proposition 1 *For $z \in (0, 3/2)$, for parameter values in which both firms have positive market shares, there is no equilibrium in which neither firm protects privacy. For small L, however, consumer welfare would be larger if neither firm protected privacy.*

Proof. See Appendix. ■

This proposition demonstrates that, at least from the point of view of consumer welfare, the equilibrium in this model tends to involve excessive privacy protection, not insufficient privacy protection. The main reason for this is that privacy protection softens competition. When firms can learn how to improve their products more the greater their market share, they have more incentive to reduce their prices to increase sales. This competition for market share benefits consumers in the form of lower prices and in the form of higher product values. Lower prices, however, do not benefit the firms. Thus, firms have an incentive to commit to protect privacy in period 0 to soften competition. It is true that privacy protection benefits some consumers. But, the firms can capture much of that benefit because protecting privacy enables a firm to either have a competitive advantage over its rival or not be at a competitive disadvantage for those privacy-valuing consumers. Since firms capture consumer benefits from protecting privacy but gain from softenting competition that hurts consumers, their incentive to protect privacy is excessive from the point of view of maximizing consumer welfare.

This do not mean that this model predicts there should be substantial privacy protection in the market. While there is no equilibrium in which neither firm protects privacy, for some parameter values, particularly if consumers do not value privacy very much, there is an equilirium in which only one firm protects privacy.

Consider an asymmetric equilibrium in which firm 0 protects privacy firm 1 does not. The conditions under which firm 0 will not deviate to not protecting privacy and firm 1 will not deviate to protecting privacy are in the appendix.[4] One can then determine the parameter regions in $(\tilde{L}, q_p, \Delta\tilde{v}^1, z)$ space in which both of these conditions hold and $\Delta\tilde{v}^1$ is small enough in magnitude that both firms have positive sales. The following graph shows the parameter value regions in $(\tilde{L}, \Delta\tilde{v}^1, z)$ space in which there is such an asymmetric equilibrium for $q_p = 1/2$. These region gets larger the smaller q_p, the fraction of consumers who value privacy.



One can then calculate consumer welfare in this region where this asymmetric equilibrum exists and what consumer welfare would be in this region were both firms required to protect privacy. The following result establishes that any regulation that mandated both firms protect privacy would either have no affect on consumer welfare or would reduce it.

Proposition 2 *Under the assumptions of the product improvement model in which both firms have positive market shares, in equilibrium, either both firms protect privacy or one firm protects privacy and one does not. If the equilibrium in which there is one firm that does not protect privacy exists, requiring both firms to protect privacy would reduce consumer welfare.*

[4] See the proofs of Propositions 1 and 2.

Proof. The proof, which is in the appendix, relies partially on numerical methods. ■

This result says that, although consumer welfare may often be greater if both firms protect privacy, if that is the case, then this will be the equilibrium in an unregulated market. As a result, the only time that regulations mandating privacy protections would change consumer welfare would be if there were an asymmetric equilibrium in which one firm does not protect privacy. This result shows that in that case, this regulation reduces consumer welfare.

3 Supplemental offering model

In this model, when each firm offers its primary good it can also offer one, and only one, additional good to each consumer (there is no product improvement in this model). Consumers need not buy the supplemental good from the same firm they buy the primary good from. For each consumer, a firm can choose to offer either good A or B, but not both, as its additional good. This is a simplified form of a general problem in which one cannot recommend too many products to a particular consumer based on its interest in another product. Doing so would cause the recommendation loses value and eliminate the benefit of focusing consumer attention and use up valuable space on a web page. Each firm can, however, offer good A to some customers and good B to others. I assume each firm can provide either good at zero marginal cost.

Every consumer has a positive value for either A or B but not both. The probability that any consumer has a positive value for A is $1/2$. If a consumer has a positive value for good $k \in \{A, B\}$ this value is v_k. If any consumer has a positive (zero) value of product k from one firm, that consumer also has the same value of product k from the other firm. The transport costs (product differentiation) for good k is t_k with $t_B \geq t_A$ for all consumers. I assume that $v_B - v_A > t_B - t_A$. For ease of presentation and tractability, I will assume consumers do not place any additional value on privacy in the supplemental good market (consumers continue to value privacy in the primary good market). If I were to include this, this would simply add on to the profit benefit from protecting privacy that exists in the primary good market.

This model is designed to capture the effects of collecting information on the ability of a firm to make product recommendations. Thus, collecting information allows the firm to better tailor its offerings to a consumer's preferences. As such, I assume a consumer's value for A and B is private information in period 1. A firm that collects information in period 1, however, will learn the consumer's value for each of these goods in period 2. At this point, to keep the analysis as simple and tractable as possible, I will simply assume this signal is perfect–a firm that does not protect privacy learns with certainty which supplemental good every consumer values.[5]

The first step to analyzing this model is to determine how firm profits in the supplemental good market vary depending on whether zero, one, or both firms know which good each consumer values. The simple case is the one in which neither firm protected privacy in period 1, so both know which good every consumer values. In this case, each firm offers every consumer the supplemental product (A or B) that this consumer values. Since every consumer can buy the supplemental product she values from either firm, we have a standard Hotelling duopoly model in which firm i earns profit of $[\frac{t_A}{2} + \frac{t_B}{2}]/2$. (The first term is the duopoly profit from selling to consumers who value A, the second is the duopoly profit of selling to consumers who value B.)

3.1 Both firms protect privacy

If both firms protect privacy in period 1, then neither knows the consumer's valuations. In this case, each firm plays a mixed strategy in terms of which product it offers. To see this, notice that, ceteris paribus, B is more profitable to offer because its value is higher and its higher transport costs reduce the competition between the firms. But, if both firms were to offer B, then each firm would earn half the standard Hotelling duopoly profit, $[\frac{t_B}{2}]/2$. A firm would like to deviate to offer A so as to earn monopoly profits selling to consumers that value A. There is no asymmetric equilibrium in which each firm offers a different product because consumers value B more than A. Hence, if one firm were charging the monopoly price for B ($v_B - t_B$), the other firm would prefer to undercut it rather than charge the monopoly price for A ($v_A - t_A$).

The fact that each firm plays a mixed strategy means that with positive probability each firm will be the only firm to offer a given product to a given consumer. Because each firm knows it will be a monopolist with positive probability, compe-

[5] The fact that a firm learns this with certainty as opposed to just receiving an imperfect signal should not affect the qualitative results. What I do lose by assuming a perfect signal is that the strength of the signal is not related to period 1 market share. This eliminates any incentive to increase period 1 market share to obtain better information. As we see from the product improvement model, this would tend to lead to lower prices and higher consumer welfare in period 1 if at least one firm collected consumer information.

tition is softer and prices will be higher. To derive the mixed strategy equilibrium, first note that the indifferent consumer for product k is located at $\frac{p_k^1 - p_k^0 + t}{2t}$ if both firms offer k. If only one firm offers k, then all its consumers buy from that firm. If firm i offers product k with probability q_k^i, ($q_{-k}^i = 1 - q_k^i$), then firm i's expected profits from offering product k are:

$$\pi_k^i = (1/2)p_k^i[q_k^{-i}(\frac{p_k^{-i} - p_k^i + t_k}{2t_k} + (1 - q_k^{-i})] \tag{2}$$

With probability q_k^{-i}, firm i must compete as a Hotelling duopolist when it offers product k, while with probability $1 - q_k^{-i}$, firm i is the only firm offering k, so it sells to the all consumers who value k.[6]

By differentiating the profit functions, and setting the first order conditions equal to zero, we can obtain equilibrium prices for both products as a function of q_k^i and q_k^{-i}.

$$p_k^i = \frac{t_k}{3q_k^i q_k^{-i}}[4q_k^{-i} + 2q_k^i - 3q_k^i q_k^{-i}] \tag{3}$$

Because each firm plays a mixed strategy, each firm must earn the same profit from offering product A as from offering product B. Using (3) in (2), one obtains profits as a function of the probability of offering each product. One can see that the two firms have symmetric profit functions, thus $q_A^0 = q_A^1 = q_A$. This makes the profit functions identical, so setting $\pi_A^0 = \pi_B^0$, one can solve for q_A. If we let $\gamma = t_B/t_A$, we have:

$$\begin{aligned} q_A \;=\; & \frac{1}{6(1+\gamma)}\{2(5-2\gamma) + \frac{2\sqrt[3]{2}(1-47\gamma+\gamma^2)}{\sqrt[3]{(\gamma-1)(2+347\gamma+2\gamma^2)+9(1+\gamma)\sqrt{3\gamma(8+359\gamma+8\gamma^2)}}} + \\ & \sqrt[3]{4[(\gamma-1)(2+347\gamma+2\gamma^2)+9(1+\gamma)\sqrt{3\gamma(8+359\gamma+8\gamma^2)}]}\} \end{aligned}$$

In the limit as $\gamma \to 1$, $q_A \to 1/2$. That is, if transport costs are equal, firms offer each product with probability one-half. As the ratio of transport costs increase, the firms offer the the product with the higher transport costs (the more profitable one, ceteris paribus) with greater probability.

One can then use this value for q_A to obtain an expression for equilibrium prices and expected profits when both firms protect privacy. The expected profits

[6] I assume the values for the products are high enough that the equilibrium prices are such that all consumers buy a product they have a positive value for.

are only a function of the transport costs of the two goods. The expression is complicated and not particularly illuminating, so I will not provide it here. But, it proves useful in determining the value of collecting consumer information.

While one might question whether firms would, in reality, play a complicated mixed strategy such as this given that it is only weakly optimal, it is worth noting that there is strong empirical support for players playing complicated mixed strategy equilibria in games without pure strategy equilibria (Chiappori 2002). In addition, for the most obvious application of the model, internet shopping sites that recommend additional products when a consumer searches for one product, it would be very easy to write code that randomly chooses between different products to offer. Given that firms like this probably do substantial experimentation involving random offers anyway, they are probably quite accustomed to having randomization in the code that determines product offerings.

3.2 One firm protects privacy

In this subsection, I analyze the equilibrium in which one firm, say firm 0, protects privacy while the other firm, firm 1, collects consumer information, so it knows which product every consumer values. In this case, firm 0 will play a mixed strategy as to which product to offer, while firm 1 will always offer the product to every consumer that she values.[7] Firm 1's profit function from selling product k remains $\pi_k^1 = (1/2)p_k^1[q_k^0(1 - \frac{p_k^1 - p_k^0 + t_k}{2t_k}) + (1 - q_k^0)]$. The only difference is that now it obtains this profit from selling both A and B. Firm 0, on the other hand, will only sell one product and when it does, it will always be competing with firm 1. So, its profit function is $\pi_k^0 = (1/2)p_k^0 \frac{p_k^1 - p_k^0 + t_k}{2t_k}$ for either $k = A$ or B but not both. Differentiating these profit functions, setting them equal to zero, and solving for prices yields:

$$p_k^0 = \frac{t_k(2 + q_k^0)}{3q_k^0}; p_k^1 = \frac{t_k(4 - q_k^0)}{3q_k^0} \tag{4}$$

Using these prices in firm 0's profit function then allows us to solve for q_A^0 that makes firm 0 indifferent between offering product A and B. The equilibrium is $q_A^0 = \frac{1 + 3\sqrt{\gamma} - \sqrt{9(1+\gamma) - 2\sqrt{\gamma}}}{2(\sqrt{\gamma} - 1)}$. As before, as $\gamma \to 1$, $q_A \to 1/2$ and q_A^0 is decreasing

[7]Firm 0 can't play a pure strategy for if she always offered product B, say, then firm 1 would charge a monopoly price for product A to those consumers who value it. This would make it more profitable for firm 0 to offer product A.

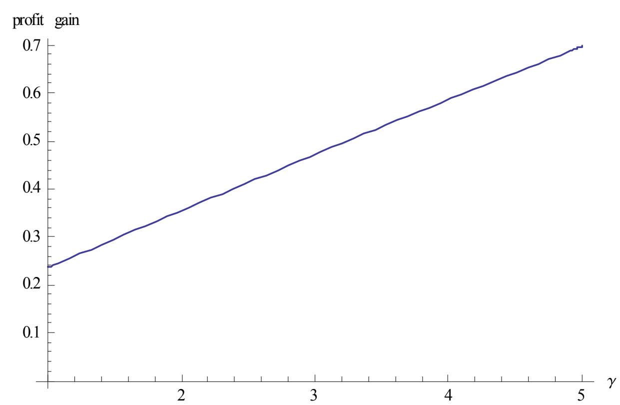


Figure 1:

in γ. Again, we can use this to determine the equilibrium pricing and expected profits for both firms when only firm 1 knows which product consumers value.

3.3 Profit gain from collecting consumer information in the supplemental good market

Now that we have derived the equilibrium profit when zero, one, or both firms know the product each consumer values, we can calculate the profit gain from having this knowledge. If a firm expects the other firm to protect privacy, then not protecting privacy moves it from the equilibrium in which neither firm has this knowledge to the equilibrium in which only it does. While the expression for profit gain is complicated and not particularly illuminating, if one measures the profit gain in units of t_A, it turns out to only depend on γ (the ratio of the two transportation costs). The following graph depicts the profit benefit as a function of γ

If the two products have the same transport costs, then acquiring consumer information about the supplemental good when the other firm does not have this knowledge, increases the acquiring firms profit by about a quarter of the transport cost. The profit gain is increasing the larger is the second product's transport cost.

As we see in the next graph, however, if a firm believes the other firm will not protect privacy, then its profits actually drop when it also does not protect privacy.

Thus, we have the following result.

Lemma 3 *In the supplemental offering model, profits in the supplemental goods*

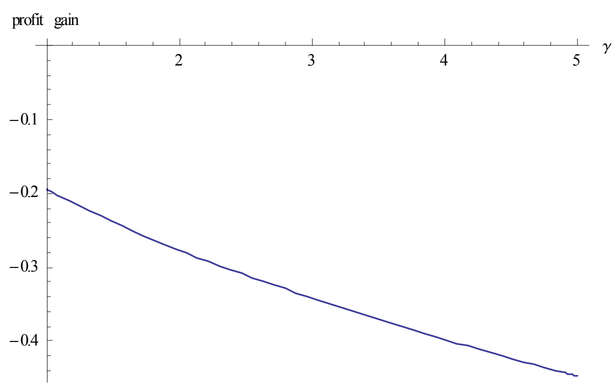


Figure 2:

market do not support an equilibrium in which neither firm protects privacy nor one in which both firms protect privacy.

When there is some uncertainty about what product the other firm will offer, competition is softened because each firm knows that there is some chance the other firm will not be offering the same product to any given consumer. Thus, firms prefer an equilibrium in which at least one firm protects privacy. Consumers, on the other hand, benefit in the supplemental goods market when neither firm protects privacy both because every consumer gets offered the product she wants from two sellers and because prices are lower due to the market being more competitive. Thus, the supplemental goods market gives firms too great an incentive to protect privacy.

3.4 Consumer versus firm benefit from privacy in the combined market

I now combine both the primary good market and the supplemental good market to examine how much consumers must value privacy in order to generate an equilibrium in which both firms protect privacy. Then I will evaluate consumer welfare at this value for privacy to determine if consumers benefit or lose when firms move to a privacy protection equilibrium.

To do this, I will focus on the base case in which the transport costs in the supplemental goods market are equal for both goods and equal to the transport cost in the primary good market. Notice that assuming equal transport costs in the supplemental goods market actually minimizes the consumer loss from protecting privacy because it stops firms from biasing which product they offer based on the difference in transport cost. I will also simplify matters by assuming equal product values in the primary good market.

In this simple case, if both firms protect privacy, then their profits in the base good market are simply $t/2$. In the supplemental goods market, with equal transport costs each firm offers each good with probability one-half. Thus, (3) implies that prices are $p = 3t$. Each firm's demand is determined as follows. A firm only offers a product that a consumer wants half the time. For that group, half the time this firm is a monopolist and half the time it competes with the other firm, so only sells to consumers on its side of the line. So, its total market share is $3/8$, giving it profits of $9t/8$. Thus, combined firm profits in the privacy equilibrium are $13t/8$.

In an equilibrium in which one firm (say 0) protects privacy, so provides the q_p consumers who value privacy with an added value of L, then, in the primary good market, standard Hotelling results show that prices are:

$$p_0 = t + q_p L/3; p_1 = t - q_p L/3$$

Among consumers who value privacy, firm 0 serves $1/2 + L(3 - 2q_p)/6t$. Among consumers who do not value privacy, firm 0 serves $1/2 - q_p L/3t$. Thus, primary good market profits are $\frac{(3t+q_pL)^2}{18t}$ for firm 0 and for $\frac{(3t-q_pL)^2}{18t}$ firm 1.

In the supplemental good market, (4) with equal transport costs and equal probability of offering each good implies that

$$p_0^s = 5t/3; p_1^s = 7t/3$$

For the half the consumers that firm 0 offers the right product for, it will serve $5/6$ of them because its price is $2t/3$ smaller. Thus, market shares are $5/12$ for firm 0 and $7/12$ for firm 1. This means that profits in the supplemental goods market are $25t/36$ for firm 0 and $49t/36$ for firm 1.

So firm 1's total profits if it does not protect privacy when firm 0 does are $\frac{(3t-q_pL)^2}{18t} + 49t/36$. If it moves to protecting privacy, then its total profits are $13t/8$. Thus, it will protect privacy, when it expects firm 0 to do so, if and only if $L \geq \frac{(6-\sqrt{19})t}{2q_p}$.

The next proposition shows that if consumers value for privacy just above the cutoff such that in equilibrium both firms will protect privacy, this equilibrium reduces consumer welfare relative to the equilibrium in which one firm protects consumer privacy.

Proposition 4 *If transport costs are equal across all market and the firms provide products of identical values, then in every equilibrium in the supplemental offering model in which one firm protects privacy and the other does not, consumer welfare is greater than it would be if both firms protected privacy. There exist values of privacy for which both firms will protect privacy but consumer welfare would be greater if only one firm protected privacy.*

Proof. See Appendix. ■

The proposition says that, like the product improvement model, firms in the supplemental offering model generally have an excessive incentive to protect privacy. Thus, this model also does not provide a justification for regulations requiring greater privacy protection. Any regulation that changes the equilibrium from one in which one firm protected privacy to one in which both firms do would necessarily reduce welfare. To the extent that this proposition supports some regulation, it suggests that in some cases regulations that limited firms ability to protect privacy might improve consumer welfare.

4 Conclusion

The public debate overfirms’ collection of customer information has been largely divorced from a rigorous economic analysis of firms’ incentives in a competitive environment in which some consumers value privacy. This project provides just such an analysis in order to shed some light on the rationale for government regulation of privacy. I explore two different explanations for why firms might want to collect consumer information: to help them improve their products and to help them identify the products consumers desire. In both models, I find that, at least for some plausible parameter values, consumers would benefit if firms were to protect privacy less than they do in equilibrium. This calls into question the consumer protection rationale for forcing greater privacy protections on firms.

Of course, unlike prior work, I do not examine the price discrimination rationale for collecting consumer information. That research shows somewhat conflicting effects of privacy regulation for this purpose. Some papers finding that privacy regulation that limits firms ability to collect consumer information for price discrimination can improve welfare and some finding that it reduces welfare.

In addition, this model analyzes only duopoly competition. While the results hold no matter how intense that duopoly competition is (as measured by the transport cost parameter), it remains for future work to analyze rigorously how the results might differ with more than two firms. That said, in many industries where this is relevant, the number of large players is quite small. For internet search engines, Google and Bing dominate the market, for example. In addition, the main effects are not likely to be dependent on only two players. If collecting consumer information provides a future benefit for current market share, then multiple firms would likely compete away this benefit just as two firms do, providing an potentially excessive incentive for privacy. Certainly, privacy regulations that limited firms' ability to do this would dampen this competition for market share among multiple firms just as they would among two.

Similarly, the supplemental offering model's main insights should apply with more than two firms as well. If collecting consumer information allows firms to target products more accurately to consumers, then this will reduce the ability of firms to serve different market niches since all firms can target each niche specifically no matter how many firms there are. As long as the ratio of some measure of the variation in consumer tastes to the number of firms is not too small, then the less knowledge there is about an individual consumer's tastes, the more effectively multiple firms can differentiate themselves based on the tastes they serve. This means that if firms protect privacy, there is some chance that for the particular collection of tastes that one firm is serving that it will have some market power for those consumers because many other firms will choose to target consumers with different tastes. On the other hand, if all firms collect consumer information, then competition will be more intense because each firm can target the particular tastes of each consumer. Thus, one should expect the key insights in this model to be fairly robust to a larger number of firms.

One might question the models in this paper on the grounds that they predict we will have excessive privacy protection when, in fact, we see very little. Notice, however, that the models often predict that there will be an equilibrium in which some firms protect privacy and some do not. In the product improvement model, the smaller firm is typically the one that will protect privacy when there is an asymmetric equilibrium. Such firms do exist. For example, in the internet search market, duckduckgo.com is a search engine that markets itself on the basis of protecting user privacy. It does not keep any user search data. Just as the model predicts, however, if consumers value privacy very little and there is substantial product improvement to be had from collecting consumer information, a privacy protecting firm like duckduckgo.com should have very little market share.

Another possible explanation is that it is hard for firms to commit to protect privacy on their own. In the model, firms want to protect privacy, at least partially, because some consumers value it. This value, however, requires that consumers can easily verify that a firm's privacy policy actually protects their privacy. Right now this seems to be very difficult given that 76 percent of Americans do not trust corporations to protect their privacy (Goel 2015). The strategic effects of protecting privacy also require that the other firm can verify that a firm is protecting privacy. If either of these is not the case, then it turns out that this market failure due to costly verification of privacy protection may actually work in consumers' favor by reducing firms' incentive to use privacy protection to soften competition. The implication that regulations that eliminate this market failure might have unintended negative consequences for consumer welfare remains.

Of course, if consumers value privacy a great deal, an equilibrium in which firms protect privacy would improve social welfare. While firms would also want this equilibrium if they could commit to it, it is possible that regulation would be necessary to enable such a commitment. This justification for regulation, however, would suggest that firms should be lobbying for privacy regulation, something that we do not see. By the same token, however, the results in this paper suggest that, in general, firms benefit more than consumers from privacy regulation. That said, this is not inconsistent with the current political state of privacy regulation. If the fraction of consumers that value privacy is small, then while privacy regulation would hurt aggregate consumer welfare more than firm profits, it might still reduce firm profits (especially if protecting privacy is costly) and could benefit the small subset of consumers who do value privacy. This might explain the current political climate.

5 Appendix

Proof. Proposition 1. If Firm 0 has positive sales in both periods, then it will not deviate from an equilibrium in which neither firms protect privacy if and only if the following is positive:

$$\begin{aligned}&(27-4z^2)^2[-81z^2+3q_p\tilde{L}(q_p\tilde{L}+2\Delta\tilde{v}^0)(-648-144z+17z^2+4z^3)\\&-2q_p\tilde{L}(5832-324z-513z^2+6z^3+10z^4)]+\\&3z\Delta\tilde{v}^0[2(27-4z^2)(5832+1701z-702z^2-198z^3+12z^4+4z^5)+\\&\Delta\tilde{v}^0(104976+67797z-4860z^2-9720z^3-1152z^4+204z^5+32z^6)]\end{aligned} \tag{5}$$

Notice that for Firm 1 not to deviate, the same condition must be positive replacing $\Delta\tilde{v}^0$ with $-\Delta\tilde{v}^0 = \Delta\tilde{v}^1$. Firm 0 will have positive sales in period 2 if and only if $\Delta\tilde{v}^1 < \frac{27-4z^2}{9+4z}$. These three conditions cannot be met simultaneously.

If $\Delta\tilde{v}^1 \geq \frac{27-4z^2}{9+4z}$, then Firm 0 has zero sales in period 2. In this case, there is no value to not protecting privacy in period 1, thus it will deviate.

Consumer welfare in a privacy equilibrium is given by:

$$CW^p = 2q_pL + v_0 + v_1 - (5t)/2 + (v_0 - v_1)^2/(18t)$$

Consumer welfare in a no privacy equilibrium is given by:

$$CW^{np} = v_0+v_1-(15-4z)t/6+(v_0-v_1)^2(81-18z-10z^2+24z^3+8z^4)/[2t(27-4z^2)^2]$$

The difference is:

$$CW^p - CW^{np} = t\{2q_p\tilde{L} - (2/3)z + \frac{z(\Delta\tilde{v}^1)^2(81-63z-108z^2-28z^3)}{9(27-4z^2)^2}\}$$

At $\tilde{L} = 0$ this is negative for any $\Delta\tilde{v}^1$ such that both firms have positive market share (upon which these welfare calculations depend). A similar calculation shows that $\tilde{L} = 0$ consumer welfare is greater in the no privacy equilibrium than the privacy equilibrim for any $\Delta\tilde{v}^1$ such that both firms have positive market share. Q.E.D. ■

Proof. Proposition 2. To have an equilibrium in which firm 0 protects privacy and firm 1 does not, firm 0 must not want to deviate to not protecting privacy. This requires that (5) is negative. Firm 1 must not want to deviate to protecting privacy. This requires that:

$$9q_p\tilde{L}^2[q_p(81-144z-37z^2+4z^3+z^4)-(27-z^2)^2]+ \tag{6}$$

$$z[(\Delta\tilde{v}^0)^2(-1296-279z+36z^2+8z^3)+6\Delta\tilde{v}^0(648+135z-18z^2-4z^3)-9z(135-4z^2)] \tag{7}$$

$$+6q_p\tilde{L}[5832+648z-297z^2-18z^3+4z^4-3\Delta\tilde{v}^0(648+144z-17z^2-4z^3)] < 0$$

Firm 0 will have positive market share with consumers who do not value privacy if and only if $\Delta\tilde{v}^0 > \frac{-54+9z+2z^2+q_p\tilde{L}(9-3z-z^2)}{3(6+z)}$. Firm 1 will have positive market share with consumers who value privacy if and only if $\Delta\tilde{v}^0 < \frac{54+9z-2z^2-\tilde{L}[27-z^2-q_p(9-3z-z^2)]}{3(6+z)}$. So, there will be an asymmetric equilibrium in which one firm protects privacy and the other one does not when (6) and (5) are negative, (6) and $\frac{-54+9z+2z^2+q_p\tilde{L}(9-3z-z^2)}{3(6+z)} < \Delta\tilde{v}^i < \frac{54+9z-2z^2-\tilde{L}[27-z^2-q_p(9-3z-z^2)]}{3(6+z)}$ for either $i = 0$ or $i = 1$. The figure in the text shows the region in which these conditions are all satisfied and the equilibrium exists for $q_p = 1/2$.

Consumer welfare in the asymmetric equilibrium is given by:

$$\begin{aligned} CW^{1p} &= v_0 + v_1 + t[q_p\tilde{L} - (5 - q_p\tilde{L}^2)/2 - (2q_p\tilde{L} - \Delta\tilde{v}^0)(4q_p\tilde{L} + \Delta\tilde{v}^0)/(18t)] + \\ & \frac{tz}{144(27 - z^2)^2}[61236 + 729z - 3564z^2 + 36z^3 + 48z^4 + (q_p\tilde{L} + \Delta\tilde{v}^0)^2(2268 + 657z - 8z^3 \\ & 18(q_p\tilde{L} + \Delta\tilde{v}^0)(648 + 171z - 10z^2 - 4z^3)] \end{aligned}$$

Thus, consumer welfare is greater in the privacy equilibrium if and only if the following is negative:

$$\begin{gathered} CW^{1p} - CW^p = \\ \frac{t}{144(27 - z^2)^2}\{-5832q_p\tilde{L}(18 - 9\tilde{L} + 8q_p\tilde{L} - 2\Delta\tilde{v}^0) + \\ z[61236 + 729z - 3564z^22 + 36z^3 + 48z^4 + (\Delta\tilde{v}^0)^2(2268 + 657z - 8z^3) \\ -18(q_p\tilde{L} + \Delta\tilde{v}^0)(648 + 171z - 10z^2 - 4z^3) \\ +72q_p\tilde{L}z(54 - z^2)(2 - \tilde{L}(1 - qp)) + 9q_p\tilde{L}(q_p\tilde{L} + 2\Delta\tilde{v}^0)(252 + 25z)]\} \end{gathered}$$

Numerical analysis in Mathematica shows that the numerical global minimum of $CW^{1p} - CW^p$ over the region in which the asymmetric equilibrium exists is positive for all $q_p \in [0,1], \tilde{L} \in [0,3], \in [-3,3]$, and $z \in [0, 3/2]$ (all necessary conditions for both firms to have positive market share). Q.E.D. ■

Proof. Proposition 3. First, I find expressions for consumer welfare if both firms protect privacy and if only one does. If both firms protect privacy, then consumer welfare in the primary market with prices of t is

$$\int_0^{1/2}(v + q_pL - t - tx)dx + \int_{1/2}^{1}(v + q_pL - t - t(1 - x))dx = v + q_pL - 5t/4$$

In the supplemental goods market, if both firms protect privacy, then prices are $3t$. Also, note that only $1/4$ of consumers can buy the product they like from either firm, while $1/2$ must buy the product they want only from one firm. $1/4$ of the consumers do not receive an offer of a supplemental good they like, so they do not buy any supplemental good. So, consumer welfare is

$$(1/4)\{\int_0^{1/2}(v^s - 3t - tx)dx + \int_{1/2}^{1}(v^s - 3t - t(1 - x))dx\} + (1/2)\{\int_0^{1}(v^s - 3t - tx)dx = 3v^s/4 - 41t/16$$

■

If only firm 0 protects privacy, then consumer welfare in the primary market is

$$(1-q_p)\{\int_0^{1/2-q_pL/3t}(v-t-tx)dx+\int_{1/2-q_pL/3t}^{1}(v-t-t(1-x))dx\}+$$

$$q_p\{\int_0^{1/2+L(3-2q_p)/6t}(v+L-t-tx)dx+$$

$$\int_{1/2+L(3-2q_p)/6t}^{1}(v-t-t(1-x))dx\}=v+q_pL/2-5t/4+L^2q_p(9-8q_p)$$

In the supplemental goods market, half the consumers have a choice of suppliers for the good they want while the other half have to buy from firm 1. So consumer welfare is

$$(1/2)\{\int_0^{5/6}(v^s-5t/3-tx)dx+\int_{5/6}^{1}(v^s-7t/3-t(1-x))dx\}+(1/2)\{\int_0^{1}(v^s-7t/3-t(1-x))dx=v^s-179t/72$$

One can use these to obtain a simple expression for the overall consumer welfare change from moving from an equilibrium in which only one firm protects privacy to one in which both do is

$$\Delta CW^s=Lq_p[18t-L(9-8q_p)]/36t-v^s/4-11t/144$$

Evaluating ΔCW^s at $L=\frac{(6-\sqrt{19})t}{2q_p}$, the value of privacy for which firm 1 will switch to protecting privacy, we obtain

$$\Delta\widehat{CW}^s=\frac{[36\sqrt{19}-165+(215-44\sqrt{19})q_p]t-12v^s}{48q_p}$$

Recall that this equilibrium assumes that v^s is large enough that all consumers purchase a supplemental good if they are offered one they value. This means that $v^s\geq 4t$. Using this minimum value, we find that

$$\Delta\widehat{CW}^s\leq\frac{[36\sqrt{19}-165+(167-44\sqrt{19})q_p]t}{48q_p}<0$$

Q.E.D.

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