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Consumer privacy in oligopolistic markets: Winners, losers, and welfare☆

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ABSTRACT

Motivated by the unprecedented availability of consumer information on the Internet, we characterize the winners and losers from potential privacy regulation in the context of four commonly-used oligopoly models: a linear city model, a circular city model, a vertical differentiation model, and a multi-unit symmetric demand model. We show that while there are winners and losers as a result of privacy enforcement, the parties who stand to benefit and the parties who stand to lose, as well as whether social welfare is enhanced or diminished, largely depends on the specific economic setting under consideration.

1. Introduction

The commercial success of the Internet has led to the proliferation of databases containing incredible amounts of consumer information. Firms, governments, data aggregators, and other interested parties can now record and analyze data about consumers at unprecedented levels of detail and speed. Nearly all US consumers now use online media to shop (BIA, 2013), and 61% of US consumers own smartphones (Deloitte, 2013). Over two thirds of online adults in the US are now registered on social networks (Pew, 2013), and 200 million individuals in North America alone have created Facebook accounts (Facebook, 2013). Coupled with the advancements in online technologies and consumers' increasing demand for them are a concomitant release of consumer information and a sharp rise in public debate about the dramatic erosion of consumer privacy.

Recent studies have focused primarily on the protection of information about a consumer's preferences or type, and the relationship between privacy and pricing. See Acquisti et al. (2014), Goldfarb and Tucker (2012), Tucker (2012), and Fudenberg and Villas-Boas (2006) for recent surveys. Fudenberg and Tirole (1998) examine the case where a firm's ability to identify consumers varies across goods. Villas-Boas (2004) and Chen and Zhang (2009) study “price for information” strategies, where firms price less aggressively in order to learn more about their customers and price discriminate in later periods. Acquisti and Varian (2005) and Conitzer et al. (2012) study models in which merchants have access to “tracking” technologies and consumers have access to “anonymizing” (or record-erasing) technologies, and show that welfare can be non-monotonic in the degree of privacy. Taylor (2004), Calzolari and Pavan (2006), and Kim and Wagman (2013) examine the exchange of consumer information among companies that are interested in discovering their reservation prices, and Burke et al. (2012) and Wagman (2014) show that even in competitive markets firms may collect excessive amounts of information about individuals.

Existing studies of the economics of privacy address several questions: Is there a demand for privacy without a taste for (or an intrinsic value of) privacy? Which consumers benefit from privacy and which consumers do not? What is the impact of consumer privacy on firms' profits and what are the overall welfare implications? The above works tackle these questions in settings where firms incur some costs in order to learn about consumer-specific characteristics; that is, costs associated with information acquisition about consumer

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preferences or types. For instance, a firm may offer introductory prices in order to induce consumers to buy and then infer information about their interests and willingness to pay — for its own products and possibly for related offerings.

In this paper, motivated by the unprecedented existing availability of consumer information, we take the alternate approach of assuming that information about consumers is already available. That is, a setting where such data has already been collected. We then re-examine the above questions in the context of oligopolistic markets, and, especially, ask: Given this unprecedented availability of consumer information, who stands to win and who stands to lose from making this information (in)accessible to firms? The answer, we show, is that it depends. To demonstrate this, we examine several work-horse oligopoly models and show that who benefits and who loses from privacy largely depends on the specific model under consideration.

In particular, we examine four fundamental models that are commonly used in the literature: (i) a linear city model (LCM), (ii) a circular city model (CCM), (iii) a vertical differentiation model (VDM), and (iv) a multi-unit symmetric demand model (MSDM). The effects of enforcing consumer privacy – in our case, by disallowing firms to tailor prices to individual consumers – are summarized in Table 1.

As indicated in Table 1, the effects of privacy are not equal across models, although the outcome is often less efficient (higher deadweight loss) with privacy, and the preference for privacy among consumers usually varies — in particular, consumers with high demand parameters for a given product tend to prefer privacy, whereas those with low demand parameters tend to prefer no privacy. Moreover, it is clear that across all four models, privacy hurts some, helps others, and does not always increase social welfare.

Our findings thus caution that studies of consumer privacy must be understood within their individual context and industries, and that their conclusions depend on the specific competitive landscapes at play — and may not necessarily apply more broadly. Furthermore, our findings demonstrate that rather than a single piece of regulation to address the decline in consumer privacy, a nuanced approach that is tailored to specific markets may be more appropriate.

The remainder of this paper is organized as follows. Sections 2 through 5 present the linear city model, the circular city model, the vertical differentiation model, and the multi-unit symmetric demand model respectively, and Section 6 concludes.

2. Linear city model

We begin by considering the celebrated linear city model (Hotelling, 1929) on the unit interval, where firm A is located at 0 and firm B at 1. Both firms' unit costs are $c>0$, and consumers' locations (addresses), $\alpha \in [0,1]$, specify their distances from 0 and are uniformly distributed. Consumers have unit-demands with valuations v, incur transportation costs t per unit distance, and the market is assumed to be covered in equilibrium, which is ensured by $v>c+\frac{3t}{2}$.

2.1. Equilibrium with privacy

When firms have no information about consumers' types, they set uniform prices. A consumer of type α^* is indifferent between purchasing from firms A and B if and only if $v-p_A-t\alpha^* = v-p_B-t(1-\alpha^*)$. That is, given

$$\alpha^* = \frac{1}{2} + \frac{p_B - p_A}{2t}. \tag{1}$$

Consumers located below (above) α^* purchase from A (B). Taking the marginal consumer into account, firms A and B maximize profits with their objectives specified by $max_{p_A}\pi_A = \alpha^*(p_A - c)$ and $max_{p_B}\pi_B = (1-\alpha^*)(p_B - c)$, respectively.

Proposition 1. *In equilibrium with privacy, prices satisfy $p_A^* = p_B^* = c+t$ and the marginal type is $\alpha^* = \frac{1}{2}$. Profits satisfy $\pi_A + \pi_B = t$, consumer surplus is $v-c-\frac{5t}{4}$, and the outcome is efficient. The minimum and maximum consumer utilities are $U(\frac{1}{2}) = v-c-\frac{3t}{2}$ and $U(0) = U(1) = v-c-t$, respectively.*

Proof. Substituting Eq. (1) into $max_{p_A}\pi_A = \alpha^*(p_A - c)$ and $max_{p_B}\pi_B = (1-\alpha^*)(p_B - c)$ and taking the first-order conditions yields $p_A = (c+t+p_B)/2$ and $p_B = (c+t+p_A)/2$. Solving for the equilibrium prices yields $p_A^* = p_B^* = c+t$, resulting in $\alpha^* = \frac{1}{2}$ and $\pi_A = \pi_B = \frac{t}{2}$, whereas $CS = 2\int_0^{\frac{1}{2}}[v-c-t-t\alpha]d\alpha = v-c-\frac{5t}{4}$. Since all consumers buy from the closer firm, the outcome is efficient. ■

2.2. Equilibrium without privacy

If consumer types are common knowledge and arbitrage is infeasible, then firms compete for each consumer, and prices are driven downward as follows:

	$p_A(\alpha)$	$p_B(\alpha)$
$\alpha \leq 0.5$	$c+t(1\text{-}2\alpha)$	c
$\alpha \geq 0.5$	c	$c+t(2\alpha\text{-}1)$

As indicated above, the resultant prices are the cost of production plus the difference in transportation costs. We have the following result.

Proposition 2. *In equilibrium without privacy, profits satisfy $\pi_A + \pi_B = \frac{t}{2}$, consumer surplus is given by $v-c-\frac{3t}{4}$, and the outcome is efficient. The minimum and maximum consumer utilities are $U(0) = U(1) = v-c-t$ and $U(\frac{1}{2}) = v-c-\frac{t}{2}$, respectively.*

Proof. In equilibrium, $\pi_A = \pi_B = \int_0^{\frac{1}{2}} t(1-2\alpha)d\alpha = \frac{t}{4}$ and $CS = 2\int_0^{\frac{1}{2}}[v-c-t(1-\alpha)]d\alpha = v-c-\frac{3t}{4}$. Since all consumers buy from the closer firm, the outcome is efficient. ■

Notice that in comparison to the outcome with complete privacy where firms charge uniform prices, all consumers are better off with individualized pricing (consumers located at points 0 and 1 are offered the same prices under both privacy regimes and are indifferent, whereas other consumers are strictly better off without privacy). Rather than compete for the marginal consumer, firms now compete for each consumer on an individual basis. Consequently, prices decrease and some rents are transferred from firms to consumers.

3. Circular city model

Consider a circular city model (Salop, 1979; Vickrey, 1999) with unit circumference and identical firms with unit production costs $c>0$ and

Table 1
Summary of results.

	LCM	CCM	VDM	MSDM
Total industry profits	Higher	Same	Higher	Lower
Consumer surplus	Lower	Lower	Lower	Higher
Deadweight loss	Same	Higher	Higher	Higher/lower
Consumers prefer privacy	None	Some	Some	Some

entry costs $f>0$. Firms are located equidistant from each other. A unit mass of consumers is uniformly distributed along the circle. Consumers continue to have unit-demands with valuations v, incur linear transportation costs t per unit distance, and we assume that the market is covered in equilibrium; that is, $v>c+\frac{3}{2}\sqrt{tf}$.

3.1. Equilibrium with privacy

When firms have no information about consumers' types, they set uniform prices. Suppose there are n firms and consider a firm i and its nearest clockwise neighbor along the circle, j. Let us refer to firm i's address as 0 and firm j's as $\frac{1}{n}$. A consumer with an address $\alpha\in(0,\frac{1}{n})$ is indifferent between purchasing from firms i and j if and only if $v-p_i-t\alpha=v-p_j-t(\frac{1}{n}-\alpha)$. That is, the marginal consumer is located at address $\alpha=\frac{1}{2n}+\frac{p_j-p_i}{2t}$.

Suppose that firm i's nearest clockwise and counter-clockwise competing neighbors charge a price p. On the relevant range for p, firm i's demand is given by

$$D_i(p_i,p)=2\alpha=\frac{1}{n}+\frac{p-p_i}{t}. \tag{2}$$

Taking its demand into account, firm i's objective is the following:

$$\max_{p_i}\pi_i=(p_i-c)\left(\frac{1}{n}+\frac{p-p_i}{t}\right)-f. \tag{3}$$

Let n_{pr}^* denote the equilibrium number of firms under the outcome with privacy. Then the following holds in equilibrium.

Proposition 3. *In equilibrium with privacy, firms' prices satisfy* $p^*=c+\frac{t}{n}$, *with* $n_{pr}^*=\sqrt{t/f}$ *firms entering and realizing zero profits. Consumer surplus is* $v-c-\frac{5}{4}\sqrt{tf}$, *and the outcome is inefficient due to excessive entry, with deadweight loss* $\frac{1}{4}\sqrt{tf}$. *The minimum and maximum consumer utilities are* $U\left(\frac{1}{2n_{pr}^*}\right)=v-c-\frac{3}{2}\sqrt{tf}$ *and* $U(0)=U\left(\frac{1}{n_{pr}^*}\right)=v-c-\sqrt{tf}$, *respectively.*

Proof. Taking the first-order condition of Eq. (3) and setting $p_i=p$ (symmetric firms), we have $p^*=c+\frac{t}{n}$. Each firm's profit is then given by $\pi=\frac{t}{n^2}-f$. Firms enter as long as there are profits, giving $n_{pr}^*=\sqrt{t/f}$. Consumer surplus satisfies $CS=2n_{pr}^*\int_0^{\frac{1}{2n_{pr}^*}}\left[v-c-\frac{t}{n}-\alpha t\right]d\alpha=v-c-\frac{5t}{4n_{pr}^*}=v-c-\frac{5}{4}\sqrt{tf}$. A social planner, in contrast, would choose n to maximize $2n\int_0^{\frac{1}{2n}}(v-c-\alpha t)d\alpha-nf=v-c-\frac{t}{4n}-nf$, resulting in $n^{SP}=\frac{1}{2}\sqrt{t/f}=\frac{1}{2}n_{pr}^*$; that is, half as many firms would enter relative to the market equilibrium. Social welfare under a planner is then $v-c-\frac{t}{4n^{SP}}-n^{SP}f=v-c-\sqrt{tf}$. Deadweight loss is $DWL=\frac{1}{4}\sqrt{tf}$. ■

3.2. Equilibrium without privacy

If consumer types are common knowledge and arbitrage is infeasible, then neighboring firms compete for each consumer, and prices are driven downward. For $\alpha\in[0,\frac{1}{n}]$, we then have:

	$p_i(\alpha)$	$p_j(\alpha)$
$\alpha\leq\frac{1}{2n}$	$c+t\left(\frac{1}{n}-2\alpha\right)$	c
$\alpha\geq\frac{1}{2n}$	c	$c+t\left(2\alpha-\frac{1}{n}\right)$

The resultant prices are thus once more the cost of production plus the difference in transportation costs. Let n_{np}^* denote the equilibrium number of firms under the outcome without privacy. We have the following result.

Proposition 4. *In equilibrium without privacy,* $n_{np}^*=\sqrt{\frac{t}{2f}}<n_{pr}^*$ *firms enter and realize zero profits. Consumer surplus is* $v-c-\frac{3}{2}\sqrt{\frac{tf}{2}}$, *and the outcome is inefficient, with deadweight loss* $\left(\frac{3}{2\sqrt{2}}-1\right)\sqrt{tf}$. *The minimum and maximum consumer utilities are given by* $U(0)=U\left(\frac{1}{n_{np}^*}\right)=v-c-\sqrt{2tf}$ *and* $U\left(\frac{1}{2n_{np}^*}\right)=v-c-\sqrt{\frac{tf}{2}}$, *respectively.*

Proof. In equilibrium, each firm's profit is $\pi=2\int_0^{\frac{1}{2n}}t\left(\frac{1}{n}-2\alpha\right)d\alpha-f=\frac{t}{2n^2}-f$, resulting in $n_{np}^*=\frac{1}{\sqrt{2}}\sqrt{t/f}$ firms entering the market. Consumer surplus satisfies $CS=2n_{np}^*\int_0^{\frac{1}{2n_{np}^*}}\left[v-c-\frac{t}{n}+\alpha t\right]d\alpha=v-c-\frac{3t}{4n_{np}^*}=v-c-\frac{3}{2\sqrt{2}}\sqrt{tf}$. A social planner, in contrast, sets $n^{SP}=\frac{1}{2}\sqrt{t/f}<n_{np}^*$, leading to a deadweight loss in the market equilibrium given by $DWL=\left(\frac{3}{2\sqrt{2}}-1\right)\sqrt{tf}$. ■

Notice that in comparison to the outcome with complete privacy where firms charge uniform prices, consumers are overall better off with individualized pricing — despite the fact that fewer firms enter the market in equilibrium. However, some individual consumers are worse off without privacy — particularly those consumers who are located nearest to firms. While firms realize zero profits in both cases, increased competition among firms due to the targeting of individual consumers leads to lower gross profits, and thus induces fewer firms to enter. Consequently, the outcome under the no-privacy regime is closer to the efficient outcome and results in a smaller deadweight loss in equilibrium.

4. Vertical differentiation model

Consider now a vertical-differentiation model (Tirole, 1988) in which two firms, L and H, produce products that are differentiated by their qualities, q_L and q_H, respectively, such that $0<q_L<q_H$. Both firms' unit costs are constant at c as before. Consumers are differentiated by their willingness to pay. In particular, consumer have types $\theta\in[\underline{\theta},\overline{\theta}]$, $0<\underline{\theta}<\overline{\theta}$, and utilities $U(q_j,p_j;\theta)=\theta q_j-p_j$ for $j\in\{L,H\}$. To focus on interior solutions, we assume that $q_L>\frac{2q_H(\overline{\theta}-2\underline{\theta})+6c}{3\overline{\theta}}$ and $\overline{\theta}>2\underline{\theta}$.

4.1. Equilibrium with privacy

Given that products differ only in consumers' willingness to pay, it is efficient for all consumers to purchase product H. However, since firms have no information about consumers' types under the privacy regime, they set uniform prices. As a result, some consumers will buy product L. The marginal consumer type θ^* is indifferent between purchasing products L and H if and only if $\theta^*q_H-p_H=\theta^*q_L-p_L$. That is, at

$$\theta^*=\frac{p_H-p_L}{q_H-q_L}. \tag{4}$$

Consumers with willingness to pay below (above) θ^* purchase product L (H). Taking the marginal consumer into account, firms L and H maximize profits with their objectives specified by $\max_{p_H}\pi_H=(\overline{\theta}-\theta^*)(p_H-c)$ and $\max_{p_L}\pi_L=(\theta^*-\underline{\theta})(p_L-c)$, respectively. In the following, let $\Delta_q=q_H-q_L$, and let CS_L and CS_H denote the surplus of consumers who buy products L and H, respectively.

Proposition 5. *In equilibrium with privacy, prices are given by* $p_H^*=\frac{1}{3}(2\overline{\theta}-\underline{\theta})\Delta_q+c$ *and* $p_L^*=\frac{1}{3}(\overline{\theta}-2\underline{\theta})\Delta_q+c$, *and the marginal type is* $\theta^*=\frac{\overline{\theta}+\underline{\theta}}{3}$. *Profits satisfy* $\pi_H=\frac{1}{9}(2\overline{\theta}-\underline{\theta})^2\Delta_q$, *and* $\pi_L=\frac{1}{9}(\overline{\theta}-2\underline{\theta})^2\Delta_q$. *The outcome is inefficient, with deadweight loss* $\frac{1}{18}(\overline{\theta}-2\underline{\theta})(\overline{\theta}+4\underline{\theta})\Delta_q$. *The minimum and maximum consumer utilities are* $U(q_L,p_L;\underline{\theta})=\underline{\theta}q_L-\frac{1}{3}(\overline{\theta}-2\underline{\theta})\Delta_q-c$ *and* $U(q_H,p_H;\overline{\theta})=\overline{\theta}q_H-\frac{1}{3}(2\overline{\theta}-\underline{\theta})\Delta_q-c$, *respectively.*

Proof. Substituting Eq. (4) into $max_{p_H}\pi_H = (\overline{\theta}-\theta^*)(p_H-c)$ and max_{p_L} $\pi_L = (\theta^*-\underline{\theta})(p_L-c)$ and taking the first-order conditions yields $p_H = (p_L + c + \overline{\theta}\Delta_q)/2$ and $p_L = (p_H + c-\underline{\theta}\Delta_q)/2$. Solving for the equilibrium prices yields $p_H^* = \frac{1}{3}(2\overline{\theta}-\underline{\theta})\Delta_q + c$ and $p_L^* = \frac{1}{3}(\overline{\theta}-2\underline{\theta})\Delta_q + c$, resulting in $\theta^* = \frac{\overline{\theta}+\underline{\theta}}{3}$, $\pi_H = \frac{1}{9}(2\overline{\theta}-\underline{\theta})^2\Delta_q$, and $\pi_L = \frac{1}{9}(\overline{\theta}-2\underline{\theta})^2\Delta_q$, whereas $CS_L = \int_{\underline{\theta}}^{\theta^*}(\theta q_L-p_L)d\theta = \frac{\overline{\theta}-2\underline{\theta}}{9}\left(\overline{\theta}\left(\frac{3q_L}{2}-q_H\right) + 2\underline{\theta}q_H-3c\right)$ and $CS_H = \int_{\theta^*}^{\overline{\theta}}(\theta q_H-p_H)d\theta = \frac{2\overline{\theta}-\underline{\theta}}{9}(\frac{3}{2}\overline{\theta}q_H + (2\overline{\theta}-\underline{\theta})q_L-3c)$. Since some consumers buy product L, the outcome is inefficient, with deadweight loss $DWL = \int_{\underline{\theta}}^{\theta^*}\Delta_q\theta d\theta = \frac{1}{18}(\overline{\theta}-2\underline{\theta})(\overline{\theta}+4\underline{\theta})\Delta_q$. ■

4.2. Equilibrium without privacy

If consumer types are common knowledge and arbitrage is infeasible, then firms compete for each consumer individually. As a result, the following holds:

$$
\begin{aligned}
p_L(\theta) &= c, \quad \theta\in[\underline{\theta},\overline{\theta}] \\
p_H(\theta) &= c + \theta\Delta_q, \quad \theta\in[\underline{\theta},\overline{\theta}].
\end{aligned}
\tag{5}
$$

Consequently, all consumers buy from firm H, which leads to an efficient outcome.

Proposition 6. *In equilibrium without privacy, profits satisfy $\pi_L = 0$ and $\pi_H = \frac{1}{2}\left(\overline{\theta}^2-\underline{\theta}^2\right)\Delta_q$, consumer surplus is given by $(\overline{\theta}-\underline{\theta})\left(\frac{1}{2}q_L(\overline{\theta}+\underline{\theta})-c\right)$, and the outcome is efficient. The minimum and maximum consumer utilities are given by $U(q_H,p_H(\underline{\theta});\underline{\theta}) = \underline{\theta}q_L-c$ and $U(q_H,p_H(\overline{\theta});\overline{\theta}) = \overline{\theta}q_L-c$, respectively.*

Proof. Given firms' pricing strategies as specified in Eq. (5), we have $\pi_L = 0$, $\pi_H = \int_{\underline{\theta}}^{\overline{\theta}}\theta\Delta_q d\theta = \frac{1}{2}\left(\overline{\theta}^2-\underline{\theta}^2\right)\Delta_q$, and $CS = \int_{\underline{\theta}}^{\overline{\theta}}\theta q_H-p_H(\theta)d\theta = \int_{\underline{\theta}}^{\overline{\theta}}\theta q_L-cd\theta = (\overline{\theta}-\underline{\theta})\left(\frac{1}{2}q_L(\overline{\theta}+\underline{\theta})-c\right)$. Since all consumers buy product H, the outcome is efficient. ■

Notice that in comparison to the outcome with complete privacy where firms charge uniform prices, some consumers are better off with individualized pricing, while others – particularly those with higher valuations – prefer privacy. The following corollary formalizes this observation.

Corollary 1. *Under vertical differentiation, consumers with types $\theta > \frac{2\overline{\theta}-\underline{\theta}}{3}$ prefer the privacy regime, and those with types $\theta < \frac{2\overline{\theta}-\underline{\theta}}{3}$ prefer no privacy. Overall profits decrease whereas consumer surplus increases under no privacy.*

Proof. In the equilibrium under no privacy, $U(q_H,p_H(\theta);\theta) = \theta q_L - c$. With privacy, consumers with $\theta > \theta^* = \frac{\overline{\theta}+\underline{\theta}}{3}$ have utility $U(q_H,p_H;\theta) = \theta q_H-\frac{1}{3}(2\overline{\theta}-\underline{\theta})\Delta_q-c$. Notice that a consumer of type $\theta > \theta^*$ prefers privacy iff $\theta q_H-\frac{1}{3}(2\overline{\theta}-\underline{\theta})\Delta_q-c > \theta q_L-c$; that is, if $\theta > \frac{2\overline{\theta}-\underline{\theta}}{3}$. Maintaining $\overline{\theta} > 2\underline{\theta}$, we have $\frac{2\overline{\theta}-\underline{\theta}}{3} > \frac{\overline{\theta}+2\underline{\theta}-\underline{\theta}}{3} = \theta^*$. Finally, under the privacy regime, for types $\theta < \theta^*$, consumer utility is given by $U(q_L,p_L;\theta) = \theta q_L-c-\frac{1}{3}(\overline{\theta}-2\underline{\theta})\Delta_q$, which is evidently lower than the utility of a consumer in this type range without privacy, given by $U(q_H,p_H(\theta);\theta) = \theta q_L - c$.

Profits with privacy are given by $\pi_L + \pi_H = \frac{1}{9}(\overline{\theta}-2\underline{\theta})^2\Delta_q + \frac{1}{9}(2\overline{\theta}-\underline{\theta})^2\Delta_q = \frac{5}{9}\Delta_q\left(\overline{\theta}^2-\frac{8}{5}\overline{\theta}\underline{\theta} + \underline{\theta}^2\right) > \frac{5}{9}\Delta_q(\overline{\theta}-\underline{\theta})^2$, which is evidently greater than total profits without privacy, $\frac{1}{2}\Delta_q(\overline{\theta}-\underline{\theta})^2$. Since overall profits decrease but the outcome is efficient without privacy, it follows that overall consumer surplus rises. ■

In the absence of privacy, more consumers purchase product H. While this clearly leads to a rise in allocative efficiency, it also results in an overall increase in consumer surplus — despite lower payoffs for consumers with higher willingness to pay. Moreover, while firm H is able to monopolize the market with individualized pricing, the potential entry of product L forces it to keep its prices below consumers' reservation values and leads to a reduction in overall industry profits.

5. Multi-unit symmetric demand model

Consider two symmetric firms with unit production costs of c. There is a population of consumers with demand parameters $\gamma\in\left[\underline{\gamma},\overline{\gamma}\right]$. A type γ consumer has demands for each good specified by

$$x_i = \gamma-p_i + bp_j, \quad i = 1, 2.$$

The measure of consumers with $\tilde{\gamma}\le\gamma$ is specified by the cumulative-density function $F(\gamma)$, where F is continuously differentiable with $\int_{\underline{\gamma}}^{\overline{\gamma}}\gamma\, dF(\gamma) \equiv \mu$. To ensure the existence of an interior equilibrium, we assume that $b \in (0,1)$ and $\underline{\gamma} > \frac{(1-b)(\mu+c)}{2-b}$.

5.1. Equilibrium with privacy

Suppose types $\gamma\in\left[\underline{\gamma},\overline{\gamma}\right]$ are private information. When firms have no information about consumers' types, they set uniform prices. In particular, firm i, $i \in \{1,2\}$, solves

$$\max_{p_i}\ E[\pi_i] = \left(\mu-p_i + bp_j\right)(p_i-c). \tag{6}$$

Proposition 7. *In equilibrium with privacy, prices satisfy $p^* = \frac{\mu+c}{2-b}$ Expected profit for each firm is $\left(\frac{\mu-(1-b)c}{2-b}\right)^2$ and consumer surplus is $E\left[\gamma^2\right]-2\mu\left(\frac{(1-b)(\mu+c)}{2-b}\right) + \left(\frac{(1-b)(\mu+c)}{2-b}\right)^2$. The outcome is inefficient, with the minimum and maximum consumer utilities given by $U\left(\underline{\gamma}\right) = \left(\underline{\gamma}-\frac{(1-b)(\mu+c)}{2-b}\right)^2$ and $U(\overline{\gamma}) = \left(\overline{\gamma}-\frac{(1-b)(\mu+c)}{2-b}\right)^2$,respectively.*

Proof. Taking the first-order condition of Eq. (6), we obtain $p_i = \frac{\mu+bp_j+c}{2}$ for $i \in \{1,2\}$. Solving for the Nash equilibrium gives $p^* = \frac{\mu+c}{2-b}$ and $E[\pi] = \int_{\underline{\gamma}}^{\overline{\gamma}}\left(\gamma-(1-b)\frac{\mu+c}{2-b}\right)\left(\frac{\mu+c}{2-b}-c\right)dF(\gamma) = \left(\frac{\mu-(1-b)c}{2-b}\right)^2$. Consumer surplus for type γ in each market is given by the area under the equilibrium demand curve and above the equilibrium price. Consumer surplus for type γ summed across both markets is then $\left(\gamma-\frac{(1-b)(\mu+c)}{2-b}\right)^2$. Aggregate consumer surplus is then given by $\int_{\underline{\gamma}}^{\overline{\gamma}}\left(\gamma-\frac{(1-b)(\mu+c)}{2-b}\right)^2dF(\gamma) = E\left[\gamma^2\right]-2\mu\left(\frac{(1-b)(\mu+c)}{2-b}\right) + \left(\frac{(1-b)(\mu+c)}{2-b}\right)^2$. ■

5.2. Equilibrium without privacy

If firms observe γ, then they price discriminate by tailoring prices to consumers based on their type. In particular, firm i, $i \in \{1,2\}$, sets individual prices to maximize the proceeds from each consumer γ by solving

$$\max_{p_i}\ \pi_i(\gamma) = \left(\gamma-p_i(\gamma) + bp_j(\gamma)\right)(p_i(\gamma)-c). \tag{7}$$

Proposition 8. *In equilibrium without privacy, prices satisfy* $\hat{p}(\gamma) = \frac{\gamma+c}{2-b}$. *Each firm's profit is given by* $\frac{E[\gamma^2]-2(1-b)c\mu+(1-b)^2c^2}{(2-b)^2}$ *and consumer surplus is* $\frac{1}{(2-b)^2}\left(E[\gamma^2]-2(1-b)c\mu+(1-b)^2c^2\right)$. *The outcome is inefficient, with the minimum and maximum consumer utilities given by* $U\left(\underline{\gamma}\right) = \left(\frac{\underline{\gamma}-(1-b)c}{2-b}\right)^2$ *and* $U(\overline{\gamma}) = \left(\frac{\overline{\gamma}-(1-b)c}{2-b}\right)^2$, *respectively.*

Proof. Taking the first-order condition of Eq. (7), we obtain $p_i(\gamma) = \frac{\gamma+bp_j+c}{2}$ for $i \in \{1,2\}$. Solving for the Nash equilibrium gives $\hat{p} = \frac{\gamma+c}{2-b}$ and $E[\pi] = \int_{\underline{\gamma}}^{\overline{\gamma}}\left(a-(1-b)\frac{\gamma+c}{2-b}\right)\left(\frac{\gamma+c}{2-b}-c\right)dF(\gamma) = \frac{E[\gamma^2]-2(1-b)c\mu+(1-b)^2c^2}{(2-b)^2}$. Consumer surplus for type γ summed across both markets is given by $\left(\gamma-\frac{(1-b)(\gamma+c)}{2-b}\right)^2$. Aggregate consumer surplus is then $\int_{\underline{\gamma}}^{\overline{\gamma}}\left(\gamma-\frac{(1-b)(\gamma+c)}{2-b}\right)^2dF(\gamma) = \frac{1}{(2-b)^2}\left(E[\gamma^2]-2(1-b)c\mu+(1-b)^2c^2\right)$. ■

Notice that in comparison to the outcome with privacy where firms charge uniform prices, consumers with types $\gamma<\mu$ are better off with individualized pricing, while those with types $\gamma>\mu$ benefit from privacy. The following corollary compares consumer surplus, profits, and welfare with and without privacy.

Corollary 2. *In the multi-unit symmetric demand model, profits are higher and consumer surplus is lower without privacy. For* $b\in[0,2-\sqrt{3})$, *overall welfare is higher with privacy, and for* $b\in(2-\sqrt{3},1]$, *welfare is higher without privacy.*

Proof. Notice that in the absence of privacy, each firm's profit rises by $\frac{E[\gamma^2]-\mu^2}{(2-b)^2}$, an amount that is strictly positive by Jensen's inequality. Similarly, the difference between consumer surplus with privacy and without privacy is given by $\frac{1}{(2-b)^2}(3-b)(1-b)\left(E[\gamma^2]-\mu^2\right)$ also positive by Jensen's inequality. Subtracting total surplus under no privacy from total surplus with privacy gives $\frac{1}{(2-b)^2}(1-(4-b)b)\left(E[\gamma^2]-\mu^2\right)$. This difference is positive for $b\in[0,2-\sqrt{3})$ and negative for $b\in(2-\sqrt{3},1]$. ■

Firms' pricing strategies in this model are strategic complements. Lower values of b reduce this complementarity feature. Firms, in effect, then behave as near-monopolists. Under the privacy regime, the welfare loss of near-monopoly pricing is partially mitigated by firms' incomplete information about consumers' demands, as firms are forced to set uniform prices. Under the no privacy regime, firms, in effect, bring the welfare distortion of a near-monopoly to individual consumers, which results in decreased consumer surplus and overall welfare but higher profits.

Higher values of b increase the complementarity of firms' pricing strategies. This feature is enhanced under the no-privacy regime, as firms take advantage of this complementarity when pricing to individual consumers, leading to an overall increase in consumers' demands. As a result, despite price discrimination and lower consumer surplus, overall welfare is increased under no privacy.

6. Conclusions

Advancements in information and communication technologies have made it critical to evaluate the tradeoffs concerning consumer privacy. In this paper, motivated by the unprecedented availability of consumer information on the Internet, we characterize the winners and losers from potential privacy regulation in the context of four familiar oligopolistic models: a linear city model, a circular city model, a vertical differentiation model, and a multi-unit symmetric demand model. The results, summarized in Table 1, demonstrate that while there are winners and losers as a result of privacy enforcement, the parties who stand to benefit and the parties who stand to lose, as well as whether social welfare is enhanced or diminished, largely depends on the specific economic model under consideration. While the effects of privacy are not equal across models, the preferences for privacy among consumers in a specific model usually vary as well — with high-demand consumers tending to prefer privacy and low-demand consumers tending to prefer no privacy.

Our findings thus caution that studies of consumer privacy must be understood within their individual context and industries, that their conclusions depend on the specific competitive landscapes at play, and that these conclusions may not necessarily extend to broader settings. Furthermore, our findings suggest that rather than a uniform piece of regulation to address the decline in consumer privacy, a nuanced approach that is individualized to specific markets may be more appropriate.

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