Private Demands and Demands For Privacy: Dynamic Pricing and the Market for Customer Information

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Abstract

Consumer privacy and the market for customer information in electronic retailing are investigated. The value of customer information derives from the ability of firms to identify individual consumers and charge them personalized prices. Two settings are studied, an anonymity regime in which sale of customer information is not possible, and a recognition regime in which a firm may compile and sell a customer list. Welfare comparisons depend critically on whether consumers anticipate sale of the list. If consumers do not foresee sale of their data, then firms possess incentives to charge higher prices under the recognition regime because this enhances the value of the list. If consumers anticipate sale of the list, then some types engage in strategic demand reduction. This undermines the market for customer information and often results in lower prices than would prevail under the anonymity regime. Firms prefer the recognition regime when consumers are myopic and the anonymity regime when consumers are strategic. More generally, welfare comparisons depend critically on demand elasticity. JEL Classifications: C73, D81, and D82.

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> Dynamic pricing is the new version of an old practice, price discrimination. It uses a potential consumer's electronic fingerprint – his record of previous purchases, his address, maybe other sites he has visited – to size up how likely he is to balk if the price is high. If the customer looks price sensitive, he gets a bargain. If he doesn't, he pays a premium.[1]

1 Introduction

In a recent survey, the Federal Trade Commission (FTC) found that 99% of on-line companies collect personal information from the individuals visiting their websites (Seligman and Taylor 2000). An article on one-to-one web marketing reports, "Most sites obtain [consumer] profile data by observing behavior on the site, tracking purchase behavior, asking questions with forms, or all three" (Allen 1999). In September 2000, Amazon.com conducted *dynamic pricing* experiments in which DVD movies were sold to different customers at different prices (up to 40% different) based on their purchasing histories (Streitfield 2000). What is more, such tailor-made prices are not restricted to transactions on the Internet. Banks, airlines, long-distance companies, and even grocery stores use modern information technology to track individual customers and make them personalized offers.[2]

Amazon was severely criticized by consumer privacy groups when news of its dynamic-pricing experiment came to light. The company publicly apologized and made refunds to 6,896 customers. Nevertheless, as Streitfield (2000) observes, "With its detailed records on the buying habits of 23 million consumers, Amazon.com is perfectly situated to employ dynamic pricing on a massive scale." Besides dynamic pricing, firms use consumer profile data to target ads and make product recommendations. Indeed, customized ads that use consumer profile data sell for ten times the price of untargeted advertisements (Schwartz 2000).

It is not necessary for electronic retailers to rely only on their own consumer-profile data. There is an active market for personal consumer information served by such web-based marketing firms as Double Click and I-Behavior. These firms collect and sell customer data that typically include an individual's: purchasing history, income, size of family, lifestyle interests, and motor vehicle ownership (Thibodeau 2001). As Rendleman (2001) puts it "Businesses are buying and selling customer data in a dizzying number of ways." Indeed, list brokers compile targetted mailing lists that sell for about $150 per 1000 names, and a good mailing list reportedly can produce millions of dollars in sales all by itself (rendleman 2001).

Indeed, customer lists and consumer profile data are often among the most valuable assets owned by electronic retailers. For instance, when web retailer, Toysmart.com, went bankrupt in June 2000, its creditors viewed Toysmart's customer list as one of its most valuable assets. Only a legal challenge by the FTC prevented sale of the list that was collected under a company privacy policy that promised customers that they "...can rest assured that your information will never be shared with a third party."[3] Similarly, Amazon's Privacy Notice currently states, "Information about our customers is an important part of our business, and we are not in the business of selling it." It, however, then goes on to say "As we continue to develop our business, *we might sell or buy* stores or assets. In such transactions, *customer information* generally is one of the transferred business assets."[4]

[1] Paul Krugman, *The New York Times* Oct. 4, 2000, A35.
[2] See, for example, Winnet (2000) and Khan (2000).
[3] See http:www.ftc.govopa200007toysmart.html.
[4] Emphasis added.

Consumers are becoming increasingly aware that their electronic purchases and other activities are being monitored, cataloged, and sold. Under pressure from consumer-privacy organizations, the FTC in March 2001 held a conference on consumer profiling and data exchange (Thibodeau 2001). The Commission's own survey results indicate that 92% of respondents do not trust on-line companies to keep their personal information confidential, and 82% agreed that the government should regulate how on-line companies use personal information.

Indeed, consumers are already taking proactive measures to ensure their privacy. Slatalla (2000) reports that, "A number of escrow services and on-line payment companies have begun to act as go-betweens to limit consumers' exposure to sellers." Services such as PrivateBuy.com use disposable credit card numbers and phoney billing addresses to create an ostensibly untraceable on-line identity for the Internet shoppers who wish to protect their privacy. Also, McCullagh (2001) reports

> Consumers are able to rely on non-governmental rating and reputation systems to steer them toward desirable destinations... TRUSTe, BBBonline, and WebTrust offer 'privacy seals' to websites so consumers can take their business to only companies they trust. TRUSTe claims it has 2000 member companies, including many high-profile sites, and BBBonline has awarded its Privacy Seal to over 500 websites.[5]

There are also other – albeit less sophisticated – strategies at the disposal of privacy-conscious electronic shoppers. Many consumers routinely refuse or remove cookies (electronic identifiers) from their computers; shop using several different computers; and pass up offers that they might otherwise be tempted to accept.

In this paper, issues concerning consumer privacy in electronic retailing are investigated in the context of a simple strategic model. While most consumers probably have an inherent preference for privacy, the analysis presented here focuses on another potentially important reason for wishing to remain anonymous, discrimination in the form of dynamic pricing. Specifically, a model featuring a continuum of consumers who wish to purchase a distinct good from each of two monopolists is explored.[6] The consumers possess heterogeneous private demands for the goods, but they are initially indistinguishable by the firms. Each consumer's valuations for the two goods are positively correlated. This implies that a consumer's purchasing decision at *firm 1* is valuable information for *firm 2*. In particular, firm 2 may wish to raise (or lower) its offer to a consumer if it learns that he did (or did not) purchase from firm 1.

Two settings are investigated, an anonymity regime in which firm 1 cannot sell or transfer customer information to firm 2, and a recognition regime in which the sale of customer information is possible. Within the context of the recognition regime, two extreme subcases are also explored, one in which consumers are myopic with regard to the sale of the customer list and one in which they fully anticipate it. In the case of myopic consumers, it is shown that firm 1 often possesses incentives to charge high *experimental* prices in order to elicit information about its customers. If consumers are myopic, then the firms prefer the recognition regime to the anonymity regime. Social surplus may be either lower or higher under the recognition regime depending respectively on whether dynamic pricing leads to higher or lower average prices.

[5] In fact, it was TRUSTe that first brought Toysmart's plan to sell its customer list to the attention of the FTC.

[6] The firms are modeled as pure monopolists in order to focus attention on information exchange. In fact, the firms could be oligopolists operating in distinct markets that feature differentiated goods or consumer search or switching costs.

In the case when consumers anticipate transfer of their information, some striking welfare reversals emerge. In particular, in equilibrium a fraction of consumers who have high valuations for both goods misrepresent their preferences by strategically refusing to buy from firm 1 if it sets a high price. This strategic demand reduction has two important consequences. First, it undermines the market for customer information because it results in a worthless customer list. Second, it causes the effective demand facing firm 1 to be more elastic, often leading to a lower price. Situations may occur, however, in which firm 1 nevertheless finds it optimal to post a high price. In this case, the dead-weight loss associated with strategic demand reduction adds to the inefficiency arising from monopoly pricing. When consumers fully anticipate sale of the customer list, the firms prefer the anonymity regime to the recognition regime. In particular, firm 1 would like to commit to a privacy policy under which it promises not to sell its customer list to firm 2. Of course, one need look no further than the landmark Toysmart case to see that such promises may be difficult to keep. Indeed, in the situation when firm 1 and firm 2 are actually a single entity selling a sequence of goods, it may be practically impossible to commit not to use customer information internally.

There are two other recent papers concerned with privacy in electronic retailing, Calzolari and Pavan (2002) and Acquisti and Varian (2002). The environment investigated by Calzolari and Pavan (2002) involves a buyer whose tastes for the goods sold by each of two firms are perfectly correlated. Interestingly, in this context the authors show that it may be optimal for the first firm to commit to disclose customer information free-of-charge to the second firm if consumers view the two goods as complements. If – as is assumed in this paper – consumer utility is separable in the two goods, however, then Calzolari and Pavan find that the first firm benefits from committing to keep customer information private. Calzolari and Pavan do not consider the possibility of myopic consumers. Also, most of their analysis is couched in the context of full commitment and design of an abstract information transmission mechanism rather than explicit sale of a customer list.

Like Calzolari and Pavan (2002), Acquisti and Varian (2002) study consumer privacy in a setting where a buyer's tastes for two goods are perfectly correlated. Acquisti and Varian, however, are primarily concerned with the design of an optimal pricing policy by a monopolist selling two goods in sequence under conditions of full commitment. While they do not explicitly consider sale of a customer list between firms, several of Acquisti and Varian's findings are similar to results presented here. For instance, they find that dynamic pricing is optimal for the monopolist when consumers are myopic but not when they are sophisticated. In particular, under full commitment, the Revelation Principle implies the optimality of eliciting a consumer's private information up front by committing to a long-term price.[7] While Acquisti and Varian study a substantially different setting than the one considered here, it is interesting to note that similar findings may arise in an environment featuring imperfectly correlated consumer tastes, a market for customer information, and absence of commitment. There are, of course, also some important differences between the settings. For example, strategic demand reduction does not occur under full commitment. Also, under full commitment and in the absence of personalized service offerings, it is optimal for the monopolist to commit to charging either a high price for both goods or a low price for both goods when consumers are sophisticated. As noted above, however, the absence of commitment results in a more elastic effective demand for the first good which can result in a low price for the first good and a high price for the second one in equilibrium.

The model presented in this paper relates to two strands of research in information economics, the rachet effect and optimal experimentation.[8] In terms of the rachet effect literature, three

[7]This echo's findings in the economics of regulation where it has been shown that a regulator should generally commit to an inflexible long-term policy (see, for example, Laffont and Tirole, 1993).

[8]This paper also contributes to the recent economic literature on 'behavior-based' price discrimination and the parallel literature in marketing on targeted pricing; e.g., Taylor (2002), Chen and Zhang (2001), Fudenberg and Tirole

papers seem most relevant. First, Hart and Tirole (1988) study a model of repeat purchases under conditions of private information by the consumer and imperfect commitment by the seller. In this context, their findings are rather stark. Specifically, Hart and Tirole find that under a long time horizon, the seller is generally compelled to charge a low price and to learn nothing until near the end of the game. This observation, however, has limited connection with the current model where there are only two periods and where learning is incomplete because of the imperfect correlation in consumer valuations.

Vincent (1998) studies a model of repeat purchases in which demand is non-stochastic and complete learning occurs in the first period when the consumer irrevocably signals his type by choosing a quantity. In Vincent's model, the seller is constrained to use linear prices, which is the reason he arrives at the opposite conclusion to that of Hart and Tirole (1988). While some elements of the environment studied by Vincent are similar to features of the current model, most of Vincent's findings and his application actually have little in common with those presented here.

In a technical sense, perhaps the paper most closely related to the current one is Kennan (2000). Kennan studies a model of persistent (but not permanent) private information. In particular, the consumer's valuation in Kennan's model follows a two-state Markov chain. The seller is assumed to know the transition probabilities governing the process, but she does not directly observe the state (high valuation or low valuation). The result is stochastic cycles in which the seller periodically 'tests' the state by posting a high price. If the consumer accepts, the seller learns that his valuation is high, and she continues to post high prices until the consumer rejects an offer. In the model presented here, by contrast, the firms do not know the state (i.e., a consumer's current valuation) or which of several stochastic processes generated it. Hence, the consumers in the current paper possess both transitory and permanent private information, and the firms learn about the permanent component over time. In terms of application, Kennan is concerned primarily with studying intertemporal linkages in labor negotiations. He does not consider the issues of consumer privacy or the market for customer information that are the core concerns of this investigation.

This paper also has connections to the literature on optimal experimentation under uncertainty or what are commonly called "bandit problems." Specifically, in a classic paper, Rothschild (1974) showed that the pricing problem facing a monopolist with unknown demand was analogous to a two-armed bandit problem. Many authors have subsequently refined and extended Rothschild's work.[9] These papers study the learning problem confronting a monopolist or oligopolist faced with stochastic market demand. In particular, customers in these models are assumed to be non-strategic. This makes sense when demand is composed of many consumers and the monopolist cannot discern or discriminate among them. As discussed above, however, many firms are now able to use modern information technology to identify individual customers and track their purchases. Hence, it is often possible to charge personalized prices based upon purchasing histories. In such environments, a model which accounts for the strategic reaction of consumers in conjunction with a firm's demand for information is essential.[10]

In the next section, the model is presented. Section 3 contains some key preliminary findings regarding the incentives for dynamic pricing. In Section 4 the anonymity regime in which the market for customer information does not exist is analyzed. The value and pricing of the customer

(2000), and Villas-Boas (1999).

[9]See, for example, Aghion, Bolton, and Jullien (1987); Mirman, Samuelson, and Urbano (1993); Rustichini and Wolinsky (1995); Keller and Rady (1999).

[10]Segal (2002) studies an interesting (and somewhat related) model in which a monopolist does not know the distribution from which its customers' valuations are drawn. Because there is unconditional correlation in buyer types, Segal shows that it is generally optimal to use a contingent pricing mechanism rather than learning through sequential sales.

list are investigated in Section 5. Section 6 contains the analysis of the recognition regime when customers do not anticipate sale of their information. The case when consumers do foresee sale of the customer list is investigated in Section 7. Concluding remarks appear in Section 8. Proofs not presented in the text appear in the Appendix.

2 The Model

2.1 The Consumers

There is a continuum of risk-neutral consumers with total mass normalized to one. A consumer's *long-run* demand parameter is denoted by $\lambda \in [0,1]$. This parameter can be thought of as a measure of income or intensity of taste for a particular class of goods. It is distributed throughout the population according to the non-degenerate distribution $F(\lambda)$. Each consumer is also associated with a distinct index $i \in [0,1]$, which can be thought of as his *address*.[11] The index i is uncorrelated with the demand parameter λ. (It is also suppressed notationally whenever it is not necessary to distinguish among consumers.)

In each period $t = 1, 2$, each consumer demands one unit of a distinct non-durable product (good t). Specifically, consumer i's valuation for good t is $v_{it} \in \{v_L, v_H\}$, where $v_H > v_L \geq 0$. Each consumer's valuations, v_{i1} and v_{i2} are determined by the outcome of two independent random variables $\tilde{v}_{i1}$ and $\tilde{v}_{i2}$, where

$$\Pr\{\tilde{v}_{it} = v_H\} = \lambda_i, \quad t = 1, 2.$$

Hence, a consumer with a high value of λ tends to have a high valuation for each of the two goods, and a consumer with a low value of λ tends to have low valuations.

2.2 The Firms

There are two risk-neutral firms (1 and 2) that have production costs of zero and that do not discount the future.[12] (It will also be instructive to consider the case when firm 1 and firm 2 are a single entity rather than two independent sellers.) Firm t is the monopoly seller of good t.

Two privacy settings are considered, the anonymity regime in which the market for customer information does not exist, and the recognition regime in which firm 1 may sell customer information to firm 2. In particular, the customer list consists of the set of first-period purchasing decisions of each consumer, $q_{i1} \in \{0, 1\}$ for all $i \in [0,1]$. In other words, the customer list merges a consumer's address with his first-period purchasing decision. If firm 2 buys the customer list from firm 1, then it can use this information to engage in dynamic pricing (i.e., it may price discriminate based on whether a consumer did or did not buy good 1).

2.3 The Game

The game unfolds in several stages. First, each consumer observes his valuations, v_{i1} and v_{i2}. The firms do not observe v_{i1}, v_{i2}, or λ_i for any consumer, but the distribution $F(\lambda)$ is common knowledge. In the second stage, firm 1 posts price $p_1 \in \Re$ for good 1.[13] It is technically convenient

[11] In this context, a consumers address is the means by which a firm recognizes him. For simplicity, it is assumed that consumers cannot hide or change their addresses. See Tadelis (1999) for a model in which firms have reputations associated with their names, and in which names may be sold.

[12] Including positive production costs and discounting would add notation without adding additional insights.

[13] Since all consumers are stochastically equivalent and have independently distributed taste parameters, there is no loss in generality (and considerable notational savings) in assuming that they all receive the same offer in the first period.

to assume that firm 2 observes the offer, p_1. Next, each consumer either accepts ($q_{i1} = 1$) or rejects ($q_{i1} = 0$) firm 1's offer. Actions in the next two stages of the game depend on the privacy regime. Specifically, under the anonymity regime, nothing happens in these stages. Under the recognition regime, however, firm 1 offers to sell its customer list for $w \in \Re$. Firm 2, then, either accepts ($x = 1$) or rejects ($x = 0$) this offer. Next, firm 2 makes offers to consumers. In particular, if firm 2 did not buy the customer list, then she posts the same price $p_{i2} = p_2$ to all consumers. Alternatively, if firm 2 did buy the list, then she offers $p_{i2} = p_2^1$ to consumers who purchased good 1 and $p_{i2} = p_2^0$ to consumers who did not.[14] Finally, each consumer either accepts ($q_{i2} = 1$) or rejects ($q_{i2} = 0$) the offer made to him.

Consumer i's payoff is

$$(v_{i1} - p_1)q_{i1} + (v_{i2} - p_{i2})q_{i2}.$$

(Note that consumer i does not regard the goods as complements or substitutes, but his valuations are unconditionally correlated as discussed in the next section.) The payoff to firm 1 under the anonymity regime is p_1Q_1, where Q_1 is the mass of consumers accepting its offer, and its payoff under the list regime is $p_1Q_1 + wx$. The payoff to firm 2 under the anonymity regime is p_2Q_2, where Q_2 is the mass of consumers accepting its offer. Its payoff under the recognition regime is

$$(1 - x)p_2Q_2 + x(p_2^1Q_2^1 + p_2^0Q_2^0) - wx,$$

where Q_2^1 and Q_2^0 are the masses of consumers accepting the offers p_2^1 and p_2^0 respectively. The solution concept for the game is an *efficient* perfect Bayesian equilibrium (PBE). In other words, if there are multiple equilibria involving different prices in which a firm earns the same payoff, then she is presumed to select the PBE with the lowest price. Similarly, if there are multiple equilibria involving different acceptance probabilities in which a consumer earns the same payoff, then he is presumed to select the PBE with the highest acceptance probability.[15]

3 Preliminary Results

Although v_{i1} and v_{i2} are independent given λ_i, their unconditional correlation is positive.[16] Specifically, a high (low) realization of v_{i1} is statistically associated with a high (low) value of λ_i, which – in turn – is associated with a high (low) realization of v_{i2}.

In fact, there are four *types* of consumers: (v_H, v_H), (v_H, v_L), (v_L, v_H), and (v_L, v_L). The mass of each type of consumer in the population is given as follows:

$$\Pr\{v_1 = v_H, v_2 = v_H\} = \int_0^1 \lambda^2 \, dF(\lambda) = E[\lambda^2], \tag{1}$$

$$\Pr\{v_1 = v_H, v_2 = v_L\} = \int_0^1 \lambda(1 - \lambda) \, dF(\lambda) = E[\lambda] - E[\lambda^2], \tag{2}$$

[14] Again, there is no loss of generality in assuming that consumers who are observationally equivalent receive the same offer.

[15] In fact, there is generically a unique PBE outcome in each varient of the game. Hence, the efficiency criterion seldom applies.

[16] Simple algebra reveals

$$\frac{Cov[v_1, v_2]}{\sqrt{Var[v_1]\,Var[v_2]}} = \frac{E[\lambda^2] - (E[\lambda])^2}{E[\lambda] - (E[\lambda])^2} > 0.$$

Observe that the numerator of the fraction on the right side of this expression is $Var[\lambda]$. Hence, if there were no uncertainty about λ, then there would be zero correlation between v_1 and v_2. In other words, it is uncertainty about λ that generates the correlation in valuations.

$$\Pr\{v_1 = v_L, v_2 = v_H\} = \int_0^1 (1-\lambda)\lambda\, dF(\lambda) = E[\lambda] - E[\lambda^2], \tag{3}$$

and

$$\Pr\{v_1 = v_L, v_2 = v_L\} = \int_0^1 (1-\lambda)^2\, dF(\lambda) = 1 - 2E[\lambda] + E[\lambda^2]. \tag{4}$$

With these expressions in hand, it is straightforward to use Bayes' rule to calculate

$$\Pr\{v_2 = v_H | v_1 = v_H\} = E[\lambda | v_1 = v_H] = \frac{E[\lambda^2]}{E[\lambda]} \tag{5}$$

and

$$\Pr\{v_2 = v_H | v_1 = v_L\} = E[\lambda | v_1 = v_L] = \frac{E[\lambda] - E[\lambda^2]}{1 - E[\lambda]}. \tag{6}$$

The following claim – which follows directly from simple algebra and the fact that $E[\lambda^2] - (E[\lambda])^2 > 0$ – shows formally that a consumer with a high (low) valuation for good 1 is more likely to have a high (low) valuation for good 2.

Lemma 1 (Monotone Likelihood Ratio Property) *For any consumer $i \in [0,1]$, the probability that $v_{i2} = v_H$ conditional on v_{i1} is higher if $v_{i1} = v_H$ than if $v_{i1} = v_L$; that is,*

$$E[\lambda | v_1 = v_H] > E[\lambda] > E[\lambda | v_1 = v_L].$$

This property is what generates firm 2's demand for customer information. Specifically, a consumer who had a high valuation for good 1 is more likely to have a high valuation for good 2. Of course, consumer valuations are never observed directly, but must be inferred from purchasing behavior.

Let k_i denote the information firm 2 knows about consumer i when she makes him an offer. In particular, if firm 2 did not buy the customer list, then $k_i = \emptyset$, and if she did buy the list, then $k_i = q_{i1}$. Firm 2's belief is, then, denoted $\Pr\{v_{i2} = v_H | k_i\}$.[17] It is also notationally convenient to define the constant

$$\nu \equiv \frac{v_L}{v_H}.$$

Finally, the equilibrium probability that consumer i accepts an offer of p_t by firm t, is called the expected demand for good t by consumer i and is denoted $D_{it}(p_t)$. It turns out that only two prices $p_t = v_L$ or $p_t = v_H$ are ever charged by either firm in equilibrium. Hence, the following definition involves no loss of generality.[18]

Definition 1 (Elasticity) *Consumer i's expected demand for good t is called elastic, unit-elastic, or inelastic respectively as $D_{it}(v_H)v_H$ is less than, equal to, or greater than $D_{it}(v_L)v_L$.*

[17] Technically, firm 2's beliefs about each individual may also depend on the mass of consumers who purchased good 1, Q_1. It turns out, however, that in each version of the model considered below, there is a unique efficient PBE outcome of the game. Moreover, the equilibrium outcome can always be supported by beliefs that do not depend on Q_1. Hence, it is without loss of generality to suppose that beliefs do not depend on this variable.

[18] The formula for arc elasticity in this context is

$$\eta \equiv -\frac{(D_{it}(v_H) - D_{it}(v_L))/(D_{it}(v_H) + D_{it}(v_L))}{(v_H - v_L)/(v_H + v_L)}.$$

It is straightforward to verify that η greater than, equal to, or less than one correspond to the respective revenue conditions given in the text.

As usual, the game is solved via backward induction. Thus, consider the continuation game played between the consumers and firm 2 under either privacy regime. Clearly, any consumer will accept an offer yielding him non-negative surplus at this juncture. In other words, consumer i will purchase good 2 if and only if $v_{i2} \geq p_{i2}$.[19] This implies that the expected demand for good 2 by consumer i is

$$D_{i2}(p_{i2}) = \begin{cases} 1, & \text{if } p_{i2} \leq v_L, \\ \Pr\{v_{i2} = v_H | k_i\}, & \text{if } p_{i2} \in (v_L, v_H], \\ 0, & \text{if } p_{i2} > v_H. \end{cases}$$

Hence, consumer i's expected demand for good 2 is elastic, unit-elastic, or inelastic respectively as $\Pr\{v_{i2} = v_H | k_i\}$ is less than, equal to, or greater than ν. This fact serves to prove the following basic observation.

Lemma 2 (Second-Period Pricing) *In any PBE, firm 2's pricing strategy must satisfy*

$$p_{i2} = \begin{cases} v_L, & \text{if } \Pr\{v_{i2} = v_H | k_i\} < \nu, \\ v_H, & \text{if } \Pr\{v_{i2} = v_H | k_i\} > \nu. \end{cases}$$

This result is simple and intuitive. Firm 2 may either offer consumer i a low price of v_L and sell to him with probability one, or she may offer him a high price of v_H and sell to him with probability $\Pr\{v_{i2} = v_H | k_i\}$. She finds the low-price strategy preferable to the high-price strategy if there is a small disparity in valuations (i.e., if ν is close to one), or if she believes strongly that $v_{i2} = v_L$.

Observe that Lemma 2 implies the potential for dynamic pricing. Specifically, if firm 2 purchases the customer list from firm 1 and if

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} < \nu < \Pr\{v_{i2} = v_H | q_{i1} = 1\},$$

then firm 2 will offer $p_2^0 = v_L$ to consumers who did not buy good 1 (because they have elastic expected demand for good 2), and $p_2^1 = v_H$ to consumers who bought good 1 (because they have inelastic expected demand for good 2).[20]

In fact, it turns out that the most information firm 2 can ever infer from observing consumer i's first-period purchasing decision is the value of v_{i1}. Hence, using (5) and (6), a necessary condition for dynamic pricing to occur in equilibrium is

$$E[\lambda | v_1 = v_L] < \nu < E[\lambda | v_1 = v_H]. \tag{7}$$

If this condition fails to hold, then firm 2's price offers will not depend on any information she learns from the customer list. In particular, if $\nu \leq E[\lambda | v_1 = v_L]$, then she always sets $p_{i2} = v_H$, and if $E[\lambda | v_1 = v_H] \leq \nu$, then she always sets $p_{i2} = v_L$. Since these cases are not very interesting, (7) is assumed to hold below. (Note that Lemma 1 implies that (7) holds for a non-negligible set of parameter values.)

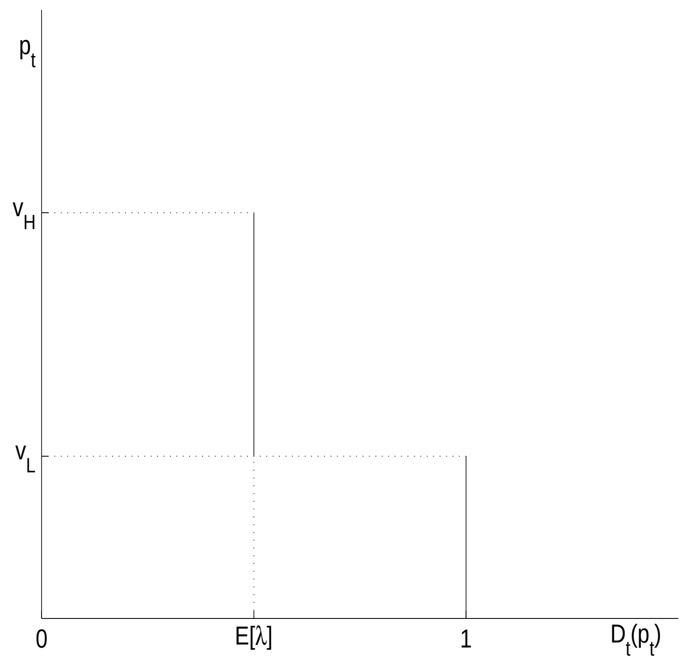
4 The Anonymity regime

It is useful to consider the bench-mark case in which firm 1 cannot disclose information to firm 2. This might occur because of legal prohibition (i.e., regulation), or because firm 1 voluntarily relinquishes the right to sell information (i.e., she adopts a binding privacy policy), or because it is simply not feasible for her to collect the information (i.e., consumers' addresses are not observable).

[19] As usual, equilibrium existence requires that *almost every* consumer i accept with probability one if $v_{i2} = p_{i2}$.

[20] If expected demand is unit-elastic, then firm 2 is indifferent between charging v_L and v_H, and equilibrium existence may require her to randomize in this case.

Figure 1: Expected Demand for Good t under the Anonymity Regime



In this setting, firm 2's beliefs must conform to the prior. In addition, there is no reason for a consumer to act strategically when contemplating the purchase of good 1. Hence, in equilibrium a consumer will accept any offer from firm t yielding non-negative surplus. Together, these observations imply that the expected demand functions of every consumer are given by (see Figure 1)

$$D_t(p_t) = \begin{cases} 1, & \text{if } p_t \leq v_L, \\ E[\lambda], & \text{if } p_t \in (v_L, v_H], \\ 0, & \text{if } p_t > v_H, \end{cases} \qquad t = 1, 2.$$

In this setting, therefore, expected demand for both goods is elastic if $E[\lambda] < \nu$ and inelastic if $E[\lambda] > \nu$. This serves as proof of the following claim.

Proposition 1 (The anonymity regime) *There is a unique efficient PBE under the anonymity regime, and equilibrium strategies are as follows:*

$$p_t = \begin{cases} v_L, & \textit{if } E[\lambda] \leq \nu, \\ v_H, & \textit{if } E[\lambda] > \nu, \end{cases}$$

$$q_{it} = \begin{cases} 1, & \textit{if } p_t \leq v_{it}, \\ 0, & \textit{if } p_t > v_{it}, \end{cases} \qquad \forall\ i \in [0,1], \quad t = 1, 2.$$

Since there is no informational linkage between the markets, the equilibrium of the two-period game is a simple repetition of the one-shot equilibrium. Note that if expected demand is elastic (or unit-elastic), then $p_1 = p_2 = v_L$, and all consumers purchase both goods with probability one.[21]

[21] There are multiple PBE *iff* expected demand is unit elastic. The efficiency criterion then dictates $p_t = v_L$ for $t = 1, 2$.

In this case, the payoff to each firm is simply v_L, and the expected payoff to a given consumer is $2E[\lambda](v_H - v_L)$. This results in the maximal social surplus of $2(E[\lambda]v_H + (1 - E[\lambda])v_L)$.

On the other hand, if expected demand is inelastic, then $p_1 = p_2 = v_H$, and a given consumer buys good t with probability $E[\lambda]$. In this case, the payoff to firm t is $E[\lambda]v_H$, and every consumer receives a payoff of zero (either because his valuation is v_L and he does not buy the good, or because he buys it at a price equal to his valuation of v_H). Hence, the value of social surplus in this case is simply $2E[\lambda]v_H$. In other words, there is dead-weight loss of $2(1 - E[\lambda])v_L$. This is just the usual monopoly distortion. The firms find it optimal to forego selling to low-value consumers in order to extract all the surplus from high-value ones. These welfare measures are useful for comparing the equilibrium outcome under the two variants of the recognition regime studied below.

5 The Market for Information

In this section, the case when sale of the customer list is feasible is investigated. In particular, equilibrium play regarding pricing and sale of the customer list are characterized.

Let $W(p_1, Q_1)$ denote the value to firm 2 from observing the customer list when the price for good 1 was p_1 and the mass of consumers accepting this offer was Q_1. Let $\hat{W}(p_1)$ be the *expected* value to firm 2 of observing the customer list (i.e., she does not observe Q_1 prior to purchasing the list). Now, since $D_1(p_1)$ is the equilibrium probability that an arbitrary consumer accepts an offer of p_1 and since there are a continuum of such consumers with total mass of one, the mass of consumers accepting the offer of p_1 in equilibrium is also $D_1(p_1)$. Equilibrium then requires

$$\hat{W}(p_1) = W(p_1, D_1(p_1)).$$

Lemma 3 (Full Extraction) *Consider the continuation game beginning at the stage when firm 1 quotes a price for the customer list. If $\hat{W}(p_1) > 0$, then in every PBE of the continuation game, firm 1 sets a price of $w = \hat{W}(p_1)$ and firm 2 purchases the list with probability one. If $\hat{W}(p_1) = 0$, then every PBE of the continuation game yields the same payoff to the firms as the PBE in which firm 1 sets a price of $w = 0$ and firm 2 purchases the list with probability one.*

This result indicates that there is no loss of generality in concentrating on equilibria in which firm 2 purchases the customer list with probability one. In other words, whenever the market for customer information exists, it is also active. Note that firm 1 extracts the full value of any information embodied in the list. This occurs because she has all the bargaining power (i.e., makes a take-it-or-leave-it offer to firm 2).[22] An implication of $w = \hat{W}(p_1)$ is that the equilibrium of the game coincides exactly with the situation in which firm 1 and firm 2 are actually a single entity. In other words, it is also appropriate to interpret the model in the context of a single monopolist that sells both goods and that keeps track of its customers' purchasing patterns.

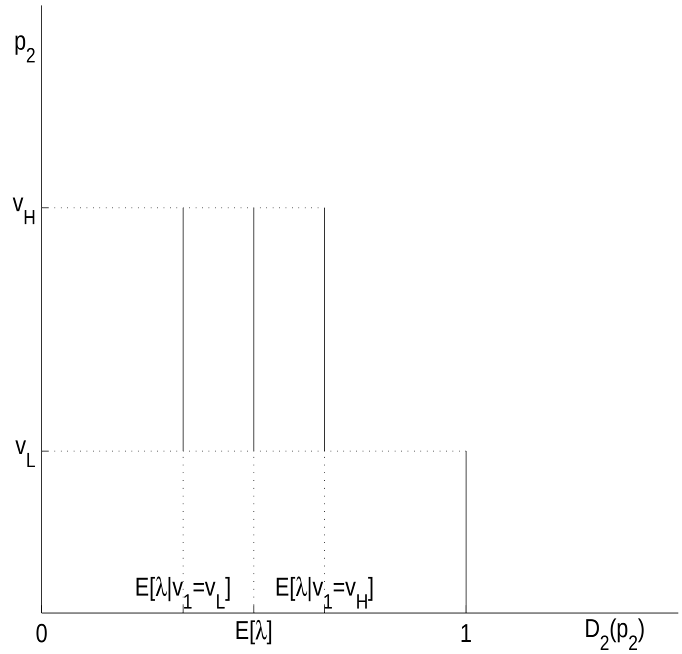
Lemma 3 implies that under the recognition regime, firm 1's pricing problem is given by

$$\max_{p_1 \in \Re} \; D_1(p_1)p_1 + \hat{W}(p_1). \tag{8}$$

Hence, to derive an equilibrium of the game under the recognition regime, the consumers' expected demand for good 1 and the corresponding value of information must be determined.

[22] An arbitrary distribution of bargaining power between the firms can be easily incorporated. The less bargaining power firm 1 possesses, the weaker are her incentives for investing in information acquisition (i.e., experimental pricing) because this investment will be 'held up' by firm 2.

Figure 2: Expected Demands for Good 2 when Consumers are Naive



6 Naive Consumers

Under the anonymity regime, the sophistication of consumers was obviously not an issue. Under the consumer recognition setting, however, it matters very much whether consumers anticipate sale of their information. It seems clear that most consumers were initially unaware that their purchasing habits and other personal data was being collected and sold over the Internet.

Naivete is modeled here by supposing that consumers are myopic. Specifically, they maximize their expected payoff in the first period without regard to how their purchasing decisions will influence the offers they receive in the second period. Under this assumption, the expected demand by any consumer for good 1 is the same as under the anonymity regime, namely

$$D_1(p_1) = \begin{cases} 1, & \text{if } p_1 \leq v_L, \\ E[\lambda], & \text{if } p_1 \in (v_L, v_H], \\ 0, & \text{if } p_1 > v_H. \end{cases}$$

Lemma 4 (The Value of Information) *The equilibrium value of the customer list to firm 2 when consumers are myopic is*

$$\hat{W}(p_1) = \begin{cases} 0, & \textit{if } p_1 \leq v_L, \\ E[\lambda^2]v_H + (1 - E[\lambda])\, v_L - \max\{v_L,\, E[\lambda]v_H\}, & \textit{if } p_1 \in (v_L, v_H], \\ 0, & \textit{if } p_1 > v_H. \end{cases}$$

To understand this result, first notice that the customer list is valuable to firm 2 only to the extent that it permits her to discriminate among consumers. If $p_1 > v_H$, then no consumers buy good 1, and if $p_1 \leq v_L$, then they all do. In either case, all the consumers are observationally equivalent, and the customer list is, therefore, worthless.

The situation is more interesting if $p_1 \in (v_L, v_H]$. In this case, types (v_H, v_H) and (v_H, v_L) buy good 1 while types (v_L, v_H) and (v_L, v_L) do not. Hence, observing q_{i1} is equivalent to observing v_{i1}. This means that the probability that consumer i will pay $p_{i2} = v_H$ for good 2 is

$$\Pr\{v_{i2} = v_H | q_{i1}\} = E[\lambda_i | v_{i1}].$$

Condition (7) and Lemma 2 then indicate that firm 2 should charge $p_2^1 = v_H$ to consumer i if he purchased good 1 and $p_2^0 = v_L$ if he did not (see Figure 2). Under this dynamic-pricing scheme, only type (v_H, v_L) consumers will not purchase good 2. Hence, from (1), (3), and (4), the revenue accruing to firm 2 from using the customer list for dynamic pricing is

$$E[\lambda^2]v_H + (1 - E[\lambda])\, v_L.$$

The value of the customer list is equal to the increase in firm 2's revenue from practicing dynamic pricing. If $v_L \geq E[\lambda]v_H$ and firm 2 did not have access to the list, then she would charge $p_2 = v_L$ to all consumers. Hence, the value of the list in this case derives from the ability to charge v_H rather than v_L to consumers who purchased good 1:

$$E[\lambda^2]v_H + (1 - E[\lambda])\, v_L - v_L = (E[\lambda | v_1 = v_H] - \nu)\, E[\lambda]v_H,$$

where the right side follows from (5). Note that this is positive by (7). Similarly, if $E[\lambda]v_H > v_L$ and firm 2 did not have access to the list, then she would charge all consumers $p_2 = v_H$. Hence, the value of the list in this case derives from the ability to charge v_L rather than v_H to consumers who did not purchase good 1:

$$E[\lambda^2]v_H + (1 - E[\lambda])\, v_L - E[\lambda]v_H = (\nu - E[\lambda | v_1 = v_L])\, (1 - E[\lambda])\, v_H,$$

where the right side follows from (6). Note that this is also positive by (7).

In order to fully characterize the equilibrium outcome of the game in this environment, define the constant

$$\overline{\gamma} \equiv \frac{1 + E[\lambda | v_1 = v_H]}{1 + E[\lambda]}.$$

Note that Lemma 1 implies $\overline{\gamma} > 1$.

Proposition 2 (Myopic Consumers) *There is a unique efficient PBE outcome of the game under the recognition regime when consumers are myopic, and it is characterized as follows.*

1. *If $\overline{\gamma}E[\lambda] \leq \nu$, then:*

- *firm 1 charges $p_1 = v_L$;*
- *all consumers purchase good 1;*
- *the customer list is worth zero;*
- *firm 2 charges $p_2^1 = v_L$ to all consumers;*
- *all consumers purchase good 2.*

2. *If $\nu < \overline{\gamma}E[\lambda]$, then:*

- *firm 1 charges $p_1 = v_H$;*
- *consumer i purchases good 1* iff *$v_{i1} = v_H$;*
- *the customer list has positive value;*

- *firm 2 charges $p_2^1 = v_H$ to consumers who purchased good 1 and $p_2^0 = v_L$ to those who did not;*
- *only type (v_H, v_L) consumers do not purchase good 2.*

The most novel aspect of this result concerns firm 1's pricing policy relative to the anonymity regime. Specifically, even though consumer demand is the same under the anonymity regime and the recognition regime with myopic consumers, firm 1 does not follow the same pricing rule in equilibrium. In particular, for $\nu \in [E[\lambda], \overline{\gamma}E[\lambda])$, it sets $p_1 = v_L$ under the anonymity regime and $p_1 = v_H$ under the recognition regime with myopic consumers. The reason for this is easily understood. Under the anonymity regime, firm 1 chooses p_1 to maximize its revenue from selling good 1, $D_1(p_1)p_1$. Under the recognition regime with myopic consumers, however, firm 1 chooses p_1 to maximize the sum of its revenue from selling good 1 and its revenue from selling the customer list, $D_1(p_1)p_1 + \hat{W}(p_1)$.

When $E[\lambda] \leq \nu$ (i.e., when expected demand is elastic), firm 1 faces a tradeoff under the recognition regime with myopic consumers. Specifically, its revenue from selling good 1 is maximized by charging $p_1 = v_L$, but this results in a worthless customer list (because all consumers buy). On the other hand, the value of the list is maximized by charging $p_1 = v_H$, but this generates less than optimal sales revenue, $E[\lambda]v_H < v_L$. So long as expected demand is not too elastic (i.e., so long as $\nu < \overline{\gamma}E[\lambda]$), firm 1 finds it optimal to sacrifice some revenue from selling good 1 in order to preserve the value of the list. That is, it *experiments* by charging a high price in order to generate valuable information. If, however, $\overline{\gamma}E[\lambda] \leq \nu$, then expected demand is so elastic that firm 1 forsakes the market for information and simply maximizes sales revenue by charging $p_1 = v_L$.

The following welfare observations follow more or less directly from Proposition 2. (Note that firm 2 is always indifferent between the recognition regime and the anonymity regime because firm 1 extracts the full value of the customer list from her. Also, type (v_L, v_L) consumers are indifferent between the two regimes because they always receive zero surplus.)

Corollary 1 (Welfare with Myopic Consumers) *When consumers are myopic, the following equilibrium welfare comparisons hold.*

1. *If $\overline{\gamma}E[\lambda] \leq \nu$, then the anonymous and recognition regimes give rise to the same efficient outcome.*

2. *If $E[\lambda] \leq \nu < \overline{\gamma}E[\lambda]$, then:*

- *type (v_H, v_H) and (v_H, v_L) consumers are better off under the anonymity regime;*
- *type (v_L, v_H) consumers are indifferent between the two regimes;*
- *firm 1 is better off under the recognition regime;*
- *social surplus is higher under the anonymity regime.*

3. *If $\nu < E[\lambda]$, then:*

- *type (v_H, v_H) and (v_H, v_L)consumers are indifferent between the two regimes;*
- *type (v_L, v_H) consumers are better off under the recognition regime;*
- *firm 1 is better off under the recognition regime;*
- *social surplus is higher under the recognition regime.*

These welfare results are easily explained. First, as noted above, if expected demand is sufficiently elastic, then firm 1 forsakes the market for information and prices at v_L. Moreover, since firm 2 learns nothing, it also prices at v_L to all of the consumers. Hence, the outcome is the same as under the anonymity regime. If, however, $\nu \in [E[\lambda], \overline{\gamma}E[\lambda])$, then firm 1 charges v_H and firm 2 prices dynamically under the recognition regime, while they both would have charged v_L under the anonymity regime. This results in higher producer surplus, lower consumer surplus, and lower total surplus over all under the recognition regime.[23] If, however, expected demand is inelastic, then the market for information creates a welfare improvement relative to the anonymity regime. In particular, dynamic pricing results in lower prices and higher sales volume for good 2.[24] Hence, the welfare impact of the market for information depends critically on what prices would be charged if sale of the customer list was not possible. It also depends critically on whether consumers anticipate sale of the list as is demonstrated in the next section.

7 Sophisticated Consumers

In this section, the unique efficient PBE outcome of the game under the recognition regime is derived, assuming that consumers fully anticipate sale of the customer list. In other words, the consumers are presumed to be just as far-sighted as the firms and to be fully strategic about revelation of their information.

The key step in the analysis is to derive the expected demand function for good 1, $D_1(p_1)$. In order to accomplish this, it is necessary to determine which types of consumers will accept which prices. Define ϕ_0 (ϕ_1) to be the probability that firm 2 charges consumer i $p_{i2} = v_L$ if $q_{i1} = 0$ ($q_{i1} = 1$). Similarly, $1 - \phi_0$ ($1 - \phi_1$)is the probability that firm 2 charges consumer i $p_{i2} = v_H$ if $q_{i1} = 0$ ($q_{i1} = 1$). In this context, Lemma 2 says that

$$\phi_{q_{i1}} = \begin{cases} 1, & \text{if } \Pr\{v_{i2} = v_H | q_{i1}\} < \nu, \\ 0, & \text{if } \Pr\{v_{i2} = v_H | q_{i1}\} > \nu. \end{cases}$$

Moreover, firm 2 is willing to randomize (i.e., choose $\phi_{q_{i1}} \in (0,1)$) if and only if $\Pr\{v_{i2} = v_H | q_{i1}\} = \nu$. (No randomizing actually occurs on the equilibrium path.)

Consumer i's expected payoff from purchasing good 1 for p_1 is, then, $v_{i1} - p_1 + \phi_1(v_{i2} - v_L)$, and his expected payoff from refusing to buy is $\phi_0(v_{i2} - v_L)$. This observation serves as proof of the following basic claim.

Lemma 5 (Consumer Incentives) *In any PBE of the game under the recognition regime with non-myopic consumers, consumer i's first-period purchase decision must satisfy*

$$q_{i1} = \begin{cases} 1, & \textit{if } v_{i1} - p_1 > (\phi_0 - \phi_1)(v_{i2} - v_L), \\ 0, & \textit{if } v_{i1} - p_1 < (\phi_0 - \phi_1)(v_{i2} - v_L), \end{cases} \quad \forall\ i \in [0,1].$$

This observation is crucial for deriving the equilibrium demand for good 1 by each type of consumer. In particular, it provides the key insight for proving the next three Lemmas.

Lemma 6 (No Signaling) *Consider the continuation game that begins after firm 1 sets p_1 under the recognition regime with forward-looking consumers.*

[23]Under the recognition regime, type (v_L, v_H) and (v_L, v_L) consumers do not buy good 1 and type (v_H, v_L) consumers do not buy good 2. This results in dead-weight loss of $\left(1 - E[\lambda^2]\right) v_L$.

[24]If expected demand is inelastic, then dead-weight loss under the anonymous regime is $2\left(1 - E[\lambda]\right) v_L$, which is easily seen to be greater than the dead-weight loss under the recognition regime of $\left(1 - E[\lambda^2]\right) v_L$.

1. *If $p_1 < v_L$, then at least one PBE of the continuation game exists, and all consumers purchase good 1 in every PBE.*

2. *If $p_1 > v_H$, then at least one PBE of the continuation game exists, and no consumer purchases good 1 in any PBE.*

The intuition behind this claim is easily grasped. It is never in a consumers immediate best interest to reject $p_1 < v_L$ or to accept $p_1 > v_H$. Hence, the only possible reason for taking such actions is to signal (via the customer list) to firm 2 that she should offer $p_{i2} = v_L$ rather than $p_{i2} = v_H$. Even so, rejecting $p_1 < v_L$ can only be profitable for type (v_L, v_H) consumers, and accepting $p_1 > v_H$ can only be profitable for type (v_H, v_H) consumers. Hence, if firm 2 observes rejection of $p_1 < v_L$ or acceptance of $p_1 > v_H$, then she must believe $v_{i2} = v_H$. But, she then wishes to set $p_{i2} = v_H$, not $p_{i2} = v_L$. In other words, the only consumers who are willing to signal that they have low valuations for good 2 actually have high valuations. Hence, signaling cannot occur in equilibrium.

Lemma 7 (Strategic Rejections) *Consider the continuation game that begins after firm 1 sets p_1 under the recognition regime with forward-looking consumers. If $p_1 \in (v_L, v_H)$, then at least one PBE of the continuation game exists, and the following claims hold in every PBE.*

1. *All type (v_L, v_L) consumers refuse to purchase good 1.*

2. *All type (v_H, v_L) consumers purchase good 1.*

3. *All type (v_L, v_H) consumers refuse to purchase good 1.*

4. *A fraction ρ^* of type (v_H, v_H) consumers refuse to purchase good 1, where*

$$\rho^* \equiv \begin{cases} \dfrac{E[\lambda]\left(E[\lambda|v_1 = v_H] - \nu\right)}{E[\lambda^2](1-\nu)}, & \text{if } E[\lambda] \leq \nu, \\ \dfrac{(1-E[\lambda])\left(\nu - E[\lambda|v_1 = v_L]\right)}{E[\lambda^2](1-\nu)}, & \text{if } E[\lambda] > \nu. \end{cases}$$

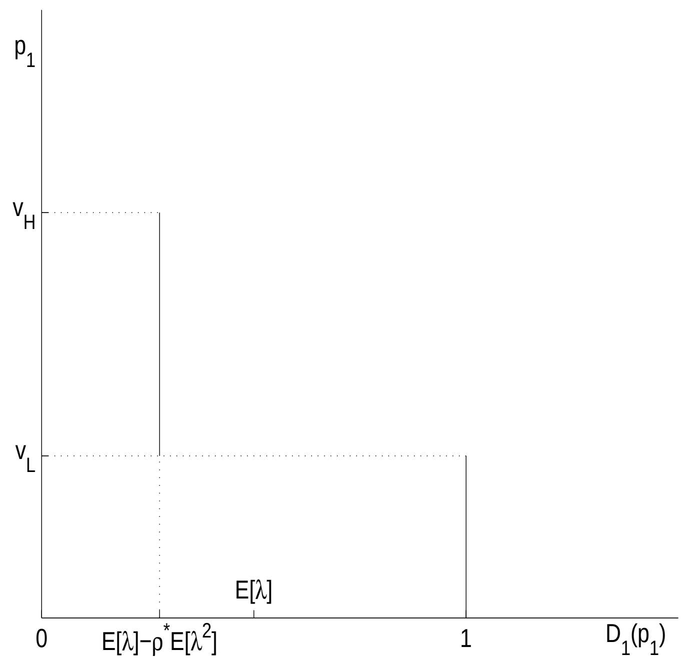
This result illustrates the key difference between the recognition regime with myopic and forward-looking consumers. Specifically, while three of the four types of consumers behave identically across the two settings, forward-looking type (v_H, v_H) consumers engage in strategic demand reduction when $p_1 \in (v_L, v_H)$. The reason for this is easily grasped.

If (as in the previous section) all type (v_H, v_H) consumers accept $p_1 \in (v_L, v_H)$, then beliefs following an acceptance are $E[\lambda|v_1 = v_H]$, and beliefs following a rejection are $E[\lambda|v_1 = v_L]$. In this case, condition (7) and Lemma 2 require $\phi_0 = 1$ and $\phi_1 = 0$ (i.e., $q_{i1} = 0$ implies $p_{i2} = v_L$ and $q_{i1} = 1$ implies $p_{i2} = v_H$). But, this cannot be an equilibrium when consumers are forward-looking because

$$v_H - p_1 < v_H - v_L.$$

In other words, given firm 2's beliefs and concomitant behavior, type (v_H, v_H) consumers would prefer to pass up the offer on good 1 in order to obtain a better offer on good 2. In fact, an analogous (but slightly more involved) argument shows that it cannot be part of an equilibrium for any fraction $\rho < \rho^*$ type (v_H, v_H) consumers to reject $p_1 \in (v_L, v_H)$. The idea is that if $\rho < \rho^*$, then the firms learn information about the type (v_H, v_H) consumers who buy good 1 that it is in their best interest to conceal (i.e., they should refuse to buy good 1).

Figure 3: Strategic Demand Reduction for Good 1



On the other hand, it is not an equilibrium for all type (v_H, v_H) consumers to pass up offers $p_1 \in (v_L, v_H)$ either. Suppose they do, then only type (v_H, v_L) consumers accept such offers, and firm 2 then wishes to set $p_{i2} = v_L$ to any consumer purchasing good 1. But, anticipating this, type (v_H, v_H) consumers actually prefer to buy good 1. Again, an analogous argument shows that it cannot be part of an equilibrium for any fraction $\rho > \rho^*$ of type (v_H, v_H) consumers to reject $p_1 \in (v_L, v_H)$. The idea here is that if $\rho > \rho^*$, then the firms learn information about the type (v_H, v_H) consumers who do not buy good 1 that it is not in their best interest to convey (i.e., they should buy good 1).

The final step in deriving the expected demand function, $D_1(p_1)$, in this setting is to identify the appropriate equilibria of the continuation game for the prices $p_1 = v_L$ and $p_1 = v_H$.

Lemma 8 (The Critical Prices) *Consider the continuation game that begins after firm 1 sets p_1 under the recognition regime with forward-looking consumers.*

1. *If $p_1 = v_L$, then there exists a PBE of the continuation game in which all consumers purchase good 1. Moreover, no other PBE of the continuation game yields a higher expected payoff to firm 1.*

2. *If $p_1 = v_H$, then there exists a PBE of the continuation game in which the purchasing pattern of the consumers coincides with the one given in Lemma 7. Moreover, no other PBE of the continuation game yields a higher expected payoff to firm 1.*

The equilibria identified in Lemma 8 are, in fact, the 'correct' equilibria of the respective continuation games in the sense that they are the ones that must be played in order to ensure existence of a solution to firm 1's pricing problem. Given this, Lemmas 6, 7, and 8 yield the following expected demand function for good 1 (see Figure 3),

$$D_1(p_1) = \begin{cases} 1, & \text{if } p_1 \le v_L, \\ E[\lambda] - \rho^* E[\lambda^2], & \text{if } p_1 \in (v_L, v_H], \\ 0, & \text{if } p_1 > v_H. \end{cases}$$

In order to fully characterize the equilibrium outcome of the game in this environment, define the constant

$$\underline{\gamma} \equiv \frac{1}{E[\lambda]} \left(1 - \sqrt{E[(1-\lambda)^2]} \right).$$

Simple algebra and the fact that $E[\lambda^2] - (E[\lambda])^2 > 0$ establish that $\underline{\gamma} < 1$.

Proposition 3 (Forward-Looking Consumers) *There is a unique efficient PBE outcome of the game under the recognition regime when consumers are forward-looking, and it is characterized as follows.*

1. *If $E[\lambda] \le \nu$, then:*

- *firm 1 charges $p_1 = v_L$;*
- *all consumers purchase good 1;*
- *the customer list is worth zero;*
- *firm 2 charges $p_2^1 = v_L$ to all consumers;*
- *all consumers purchase good 2.*

2. *If $\underline{\gamma} E[\lambda] \le \nu < E[\lambda]$, then:*

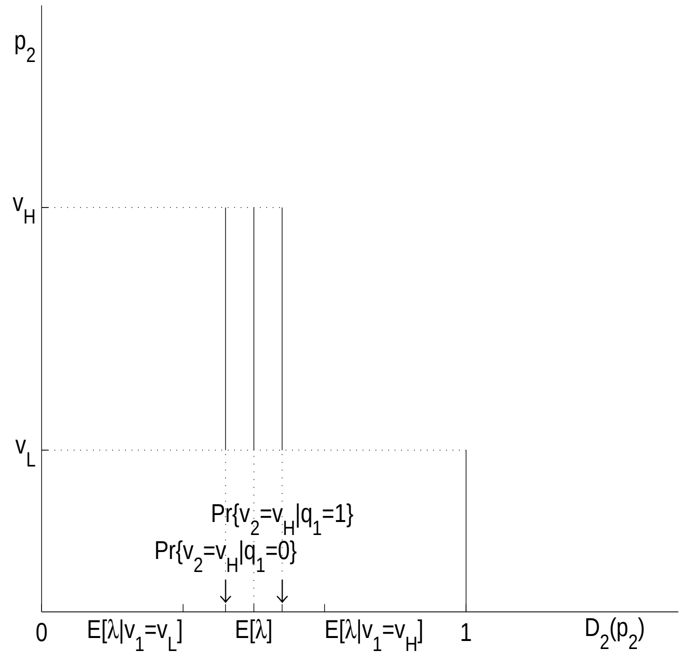
- *firm 1 charges $p_1 = v_L$;*
- *all consumers purchase good 1;*
- *the customer list is worth zero;*
- *firm 2 charges $p_2^1 = v_H$ to all consumers;*
- *consumer i purchases good 2* iff $v_{i2} = v_H$.

3. *If $\underline{\gamma} E[\lambda] > \nu$, then:*

- *firm 1 charges $p_1 = v_H$;*
- *the purchasing pattern of consumers coincides with the one given in Lemma 7;*
- *the customer list is worth zero;*
- *firm 2 charges $p_2^0 = p_2^1 = v_H$ to all consumers;*
- *consumer i purchases good 2* iff $v_{i2} = v_H$.

This result exhibits some rather striking reversals from the naive-consumer setting. In particular, the strategic rejections by type (v_H, v_H) consumers lead to a more elastic expected demand function and a correspondingly larger range of parameter values over which firm 1 finds it optimal to set a low price. Hence, for $\nu \in [\underline{\gamma} E[\lambda], \overline{\gamma} E[\lambda])$, firm 1 sets $p_1 = v_L$ if consumers are sophisticated while she sets $p_1 = v_H$ if they are naive. The reason for this difference is easy to understand. Recall that if consumers are naive and $\overline{\gamma} E[\lambda] > \nu$, firm 1 sets $p_1 = v_H$ in order to maximize the sum of the revenue from selling good 1 and the revenue from selling the customer list. If consumers are

Figure 4: Expected Demands for Good 2 when Consumers are Forward-Looking



sophisticated, however, then the 'effective' expected demand for good 1 is lower and (perhaps most strikingly) the customer list is always worth zero. Thus, firm 1 finds it optimal to set $p_1 = v_L$ when $\underline{\gamma}E[\lambda] \leq \nu$ (i.e., when effective expected demand is elastic) in order to maximize the revenue from selling good 1 alone. Note, in fact, that when $\nu \in [\underline{\gamma}E[\lambda], E[\lambda])$, expected demand for good 1 is elastic (because of the strategic demand reduction), while expected demand for good 2 is inelastic. Hence, in this region of the parameter space, $p_1 = v_L$ and $p_{i2} = v_H$ for $i \in [0, 1]$. In other words, firm 1 receives a lower price and lower profit than firm 2 because of the strategic demand reduction for good 1.

Indeed, the customer list is worthless when consumers are sophisticated precisely because of the strategic rejections by type (v_H, v_H) consumers. In particular, if $E[\lambda] \leq \nu$, then ρ^* is calibrated so that

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} < \nu = \Pr\{v_{i2} = v_H | q_{i1} = 1\}.$$

(See Figure 4.) In this instance, however, Lemma 2 indicates that it is (weakly) optimal for firm 2 to set $p_{i2} = v_L$ even if $q_{i1} = 1$. In other words, purchase of good 1 does not provide a strong enough signal that $v_{i2} = v_H$ to justify dynamic pricing. Similarly, if $E[\lambda] > \nu$, then ρ^* is calibrated so that

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} = \nu < \Pr\{v_{i2} = v_H | q_{i1} = 1\}.$$

In this case, Lemma 2 indicates that it is (weakly) optimal for firm 2 to set $p_{i2} = v_H$ even if $q_{i1} = 0$. In other words, refusal to purchase good 1 does not provide a strong enough signal that $v_{i2} = v_L$ to justify dynamic pricing.

The following welfare observations follow more or less directly from Proposition 3. (Note that firm 2 is always indifferent between the recognition regime and the anonymity regime because she learns no valuable information in either case and consumers behave identically in the second period under either regime. Also, type (v_L, v_L) consumers are indifferent between the two regimes because they always receive zero surplus.)

Corollary 2 (Welfare with Forward-Looking Consumers) *When consumers are forward-looking, the following equilibrium welfare comparisons hold.*

1. *If* $E[\lambda] \leq \nu$*, then the anonymous and recognition regimes give rise to the same efficient outcome.*

2. *If* $\underline{\gamma}E[\lambda] \leq \nu < E[\lambda]$*, then:*
   - *type* (v_H, v_H) *and* (v_H, v_L) *consumers are better off under the recognition regime;*
   - *type* (v_L, v_H) *consumers are indifferent between the two regimes;*
   - *firm 1 is better off under the anonymity regime;*
   - *social surplus is higher under the recognition regime.*

3. *If* $\nu < \underline{\gamma}E[\lambda]$*, then:*
   - *type* (v_H, v_H) *and* (v_H, v_L) *consumers are indifferent between the two regimes;*
   - *type* (v_L, v_H) *consumers are better off under the recognition regime;*
   - *firm 1 is better off under the anonymity regime;*
   - *social surplus is higher under the anonymity regime.*

These welfare results are easily explained. First, if $E[\lambda] \leq \nu$, then expected demand is elastic under both regimes and firm 1 optimally prices at $p_1 = v_L$. Moreover, since firm 2 learns nothing, it also prices at $p_{i2} = v_L$ to all of the consumers. If, however, $\nu \in [\underline{\gamma}E[\lambda], E[\lambda])$, then firm 1 charges $p_1 = v_L$ under the recognition regime (because effective expected demand is elastic) and $p_1 = v_H$ under the anonymity regime (because expected demand is inelastic). Firm 2 learns no valuable information under either regime and, therefore, sets $p_{i2} = v_H$ to all consumers under both regimes. The lower price for good 1 under the recognition regime results in higher consumer surplus, lower producer surplus, and higher total surplus over all. If, however, $\nu < \underline{\gamma}E[\lambda]$, then expected demand is inelastic in both periods under both regimes and prices are always v_H. While the consumers are obviously, therefore, indifferent between the two settings, firm 1 prefers the anonymity regime where it earns $E[\lambda]v_H$ rather than $\left(E[\lambda] - \rho^* E[\lambda^2]\right) v_H$. Indeed, the dead-weight loss created by strategic demand reduction in this case exacerbates the inefficiency due to monopoly pricing.

Note that – in contrast to the case of myopic consumers – when consumers are forward looking, firm 1 always (weakly) prefers the anonymity regime to the recognition regime. In other words, firm 1 would like to publicly adopt a policy that committed her not to sell the customer list. Without such a commitment, she faces strategic demand reduction that both reduces her sales revenue and undermines the market for information. A commitment not to sell the customer list is, however, not always good for consumers or for social surplus. In particular, the fact that expected demand is more elastic under the recognition regime can induce firm 1 to post a lower price which generates higher sales volume than under the anonymity regime. When expected demand is quite inelastic, however, a commitment not to sell the customer list enhances welfare. While it does not solve the problem of monopoly pricing, it does eliminate the dead-weight loss of $\rho^* E[\lambda^2] v_H$ due to strategic demand reduction.

8 Conclusion

At its core, this paper is concerned with property rights. Does a firm have the right to collect and sell valuable information about the identity and purchasing habits of its customers, or do consumers have the right to anonymity? Both settings were analyzed in the context of a simple strategic model without commitment.

It was shown that firms fare well under a customer recognition regime when consumers do not anticipate sale of their information. Indeed, in such a setting the opportunity to sell its customer list often gives a firm incentives to charge high experimental prices. Such experimentation unambiguously lowers welfare because the loss in consumer surplus outweighs the value of the information obtained by the firms. When demand is very inelastic, however, welfare is actually higher under the recognition regime when consumers are myopic because firms offer lower prices to customers who did not previously purchase.

These welfare comparisons are modified sharply if consumers anticipate sale of the list. In this case, some consumers with high valuations engage in strategic demand reduction when confronted with high prices. This has two important consequences. First, it undermines the market for customer information since it results in a worthless customer list. Second, effective demand becomes more elastic which can lead to lower equilibrium prices and higher welfare. Indeed, when consumers anticipate sale of the customer list, the firms would prefer to commit to not selling it; i.e., to adopt a binding privacy policy. Perhaps surprisingly, adoption of such a policy is not always good for welfare.

This paper is an early exploration of a vein of research that is rich and relatively untapped. The growing ability of firms to store and recall customer information is reshaping markets and changing the landscape of competition. For instance, one often-proclaimed benefit of a customer recognition regime is that it reduces consumer search by allowing firms to recommend products and services in accordance with consumer profile data. This potential benefit was not captured in the model presented above, and it would be interesting to see how it might modify the findings. There are also interesting issues concerning the mode of competition in markets where information about customers is fast becoming an essential ingredient for success. Finally, there are a host of open policy questions surrounding privacy rights in electronic retailing. In short, it is safe to say that economists and policy makers are only beginning to understand the social costs and benefits of the market for customer information and consumer privacy.

Appendix

Proof of Lemma 3

Clearly, firm 2's best-response is to accept $w < \hat{W}(p_1)$ with probability one, to reject $w > \hat{W}(p_1)$ with probability one, and to mix between accepting and rejecting $w = \hat{W}(p_1)$ with any probability.

- First, suppose $\hat{W}(p_1) > 0$, then, firm 1 wishes to post the highest value of w that firm 2 will accept with probability one. If firm 2 rejects $w = \hat{W}(p_1)$ with positive probability, then a solution to firm 1's problem (and hence an equilibrium) does not exist (i.e., there is an open-set problem). Hence, in equilibrium firm 1 sets $w = \hat{W}(p_1)$, and firm 2 purchases the list with probability one.
- Next, suppose $\hat{W}(p_1) = 0$. Then any $w \in \Re_+$ and any selection from firm 2's best-response correspondence can evidently occur as part of a PBE of the continuation game. Moreover, the firms are obviously indifferent among these equilibria. ■

Proof of Lemma 4

First note that if $p_1 \leq v_L$ or $p_1 > v_H$, then all consumers act identically, either purchasing or not purchasing good 1 respectively. Hence, firm 2 learns nothing that permits her to update her beliefs, and the customer list is, therefore, worthless to her. Now consider $p_1 \in (v_L, v_H]$. At these prices, consumers with $v_1 = v_H$ buy good 1 and consumers with $v_1 = v_L$ do not. Hence, observing q_{i1} is equivalent to observing v_{i1}. Condition (7) and Lemma 2 then indicate that it is optimal to charge $p_2^1 = v_H$ to consumers who bought good 1 and $p_2^0 = v_L$ to those who did not. Under this dynamic-pricing scheme, type (v_H, v_H) consumers will buy and type (v_H, v_L) consumers will not buy good 2 for v_H, and type (v_L, v_H) and type (v_L, v_L) consumers will buy good 2 for v_L. Using expressions (1) through (4), the revenue earned by firm 2 when she observes the customer list is thus

$$E[\lambda^2]v_H + (1 - E[\lambda])\, v_L.$$

In order to compute the value of the customer list, it is necessary to subtract from this the payoff that firm 2 would receive if she did not purchase the list. Lemma 2 indicates that this is precisely $\max\{v_L,\, E[\lambda]v_H\}$.

To verify that $\hat{W}(p_1)$ is non-negative, first suppose $v_L \geq E[\lambda]v_H$. Then,

$$\hat{W}(p_1) = E[\lambda^2]v_H - E[\lambda]v_L.$$

Factoring $E[\lambda]v_H$ out of both terms on the right and invoking (5) gives

$$\hat{W}(p_1) = (E[\lambda|v_1 = v_H] - \nu)\, E[\lambda]v_H.$$

This is positive by (7). Next, suppose $E[\lambda]v_H \geq v_L$. Then,

$$\hat{W}(p_1) = (1 - E[\lambda])\, v_L - \Big(E[\lambda] - E[\lambda^2]\Big)\, v_H.$$

Factoring $(1 - E[\lambda])\, v_H$ out of both terms on the right and invoking (6) gives

$$\hat{W}(p_1) = (\nu - E[\lambda|v_1 = v_L])\, (1 - E[\lambda])\, v_H.$$

This is also positive by (7). ■

Proof of Proposition 2

First, note from the specification of expected demand and from the formula for $\hat{W}(p_1)$ given in (4), that one of two prices $p_1 = v_L$ or $p_1 = v_H$ must be optimal for firm 1.

- First, suppose $E[\lambda] \leq \nu$. If firm 1 sets $p_1 = v_H$, then she earns revenue from selling good 1 of $E[\lambda]v_H$ and revenue from selling the customer list of $E[\lambda^2]v_H - E[\lambda]v_L$. If she sets $p_1 = v_L$, then she earns revenue from selling good 1 of v_L and revenue from selling the customer list of zero. Simple algebra then reveals

$$E[\lambda]v_H + E[\lambda^2]v_H - E[\lambda]v_L \leq v_L \;\Leftrightarrow\; \overline{\gamma}E[\lambda] \leq \nu.$$

- Next, suppose $E[\lambda] > \nu$. If firm 1 sets $p_1 = v_H$, then she earns revenue from selling good 1 of $E[\lambda]v_H$ and revenue from selling the customer list of $\left(E[\lambda^2] - E[\lambda]\right)v_H + \left(1 - E[\lambda]\right)v_L$. If she sets $p_1 = v_L$, then she earns revenue from selling good 1 of v_L and revenue from selling the customer list of zero. Simple algebra and expression (5) then reveal

$$E[\lambda]v_H + \Big(E[\lambda^2] - E[\lambda]\Big)\, v_H + \left(1 - E[\lambda]\right) v_L > v_L \;\Leftrightarrow\; E[\lambda | v_1 = v_H] > \nu.$$

  This holds by condition (7).

The rest of the claim follows directly from Lemmas 2 and 4. In particular, note that firm 2's beliefs off the equilibrium path (e.g., if $Q_1 \neq D_{i1}(p_1)$) are irrelevant when consumers are myopic. ■

Proof of Lemma 6

1. Suppose $p_1 < v_L$.

- First it is shown that all consumers buy good 1 in every PBE of the continuation game. Note that Lemma 5 indicates that all type (v_H, v_H), (v_H, v_L), and (v_L, v_L) consumers will purchase good 1 because

$$v_{i1} - p_1 > (\phi_0 - \phi_1)(v_{i2} - v_L), \quad \forall\, \phi_0 \text{ and } \phi_1 \in [0, 1].$$

  To see that all type (v_L, v_H) consumers must also buy, suppose to the contrary that there is a PBE in which a positive measure of type (v_L, v_H) consumers refuse to buy good 1. Then since all other types accept the offer, firm 2 knows which type of consumer she faces following a rejection. In particular, $\Pr\{v_{i2} = v_H | q_{i1} = 0\} = 1$. Lemma 2 then gives $\phi_0 = 0$. But then

$$v_L - p_1 > (0 - \phi_1)(v_H - v_L), \quad \forall\, \phi_1 \in [0, 1].$$

  In other words, Lemma 5 indicates that all type (v_L, v_H) consumers strictly prefer to purchase good 1, contrary to supposition.

- To establish existence, observe that the belief function

$$\Pr\{v_{i2} = v_H | q_{i1}\} = \begin{cases} E[\lambda], & \text{if } q_{i1} = 1, \\ 1, & \text{if } q_{i1} = 0, \end{cases}$$

  supports the outcome in which all consumers buy good 1 as a PBE of the continuation game.

2. Suppose $p_1 > v_H$.

- First it is shown that no consumer buys good 1 in any PBE of the continuation game. Note that Lemma 5 indicates that all type (v_H, v_L), (v_L, v_H), and (v_L, v_L) consumers will refuse to purchase good 1 because

$$v_{i1} - p_1 < (\phi_0 - \phi_1)(v_{i2} - v_L), \quad \forall\ \phi_0 \text{ and } \phi_1 \in [0, 1].$$

  To see that all type (v_H, v_H) consumers must also refuse to buy, suppose to the contrary that there is a PBE in which a positive measure of type (v_H, v_H) consumers buy good 1. Then since all other types reject such an offer, firm 2 knows which type of consumer she faces following an acceptance. In particular, $\Pr\{v_{i2} = v_H | q_{i1} = 1\} = 1$. Lemma 2 then gives $\phi_1 = 0$. But then

$$v_H - p_1 < (\phi_0 - 0)(v_H - v_L), \quad \forall\ \phi_0 \in [0, 1].$$

  In other words, Lemma 5 indicates that all type (v_H, v_H) consumers strictly prefer not to purchase good 1, contrary to supposition.

- To establish existence, observe that the belief function

$$\Pr\{v_{i2} = v_H | q_{i1}\} = \begin{cases} 1, & \text{if } q_{i1} = 1, \\ E[\lambda], & \text{if } q_{i1} = 0, \end{cases}$$

  supports the outcome in which no consumers buy good 1 as a PBE of the continuation game. ■

Proof of Lemma 7

Suppose $p_1 \in (v_L, v_H)$. The first four steps of this proof demonstrate that only the behavior described in the lemma can occur in a PBE of the continuation game. The final step then verifies that a PBE involving this behavior exists.

1. Note that

$$v_L - p_1 < (\phi_0 - \phi_1)(v_L - v_L), \quad \forall\ \phi_0 \text{ and } \phi_1 \in [0, 1].$$

Hence, Lemma 5 indicates that no type (v_L, v_L) consumers will purchase good 1 in any PBE of the continuation game.

2. Note that

$$v_H - p_1 > (\phi_0 - \phi_1)(v_L - v_L), \quad \forall\ \phi_0 \text{ and } \phi_1 \in [0, 1].$$

Hence, Lemma 5 indicates that all type (v_H, v_L) consumers will purchase good 1 in every PBE of the continuation game.

3. To see that no type (v_L, v_H) consumers will purchase good 1 in any PBE of the continuation game, suppose to the contrary that there is a PBE in which a fraction $\alpha > 0$ of type (v_L, v_H) consumers purchase good 1. A necessary condition for this is

$$v_L - p_1 \geq (\phi_0 - \phi_1)(v_H - v_L).$$

Since the left side of this inequality is negative, it must be that $\phi_0 < \phi_1$. This being the case, note that

$$v_H - p_1 > (\phi_0 - \phi_1)(v_H - v_L).$$

Hence, all type (v_H, v_H) consumers purchase good 1 in this PBE. Combining this with the previous two parts of the proof and using (1) through (4) gives

$$\Pr\{v_{i2} = v_H | q_{i1} = 1\} = \frac{E[\lambda^2] + \alpha\left(E[\lambda] - E[\lambda^2]\right)}{E[\lambda] + \alpha\left(E[\lambda] - E[\lambda^2]\right)}$$

and

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} = \frac{(1-\alpha)\left(E[\lambda] - E[\lambda^2]\right)}{1 - 2E[\lambda] + E[\lambda^2] + (1-\alpha)\left(E[\lambda] - E[\lambda^2]\right)}.$$

The first of these expressions is increasing and the second is decreasing in α. Moreover, for $\alpha = 0$, the first expression equals $E[\lambda | v_1 = v_H]$ and the second equals $E[\lambda | v_1 = v_L]$. Applying (7) then yields

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} < \nu < \Pr\{v_{i2} = v_H | q_{i1} = 1\}.$$

But, Lemma 2 then dictates that $\phi_0 = 1$ and $\phi_1 = 0$, in which case

$$v_L - p_1 < (\phi_0 - \phi_1)(v_H - v_L).$$

But then, Lemma 5 indicates that no type (v_L, v_H) consumers buy good 1, contrary to supposition.

4. Showing that a fraction ρ^* of type (v_H, v_H) consumers reject p_1 in any PBE is slightly involved. First, for $\rho \in [0,1]$, define the functions

$$\pi_0(\rho) = \frac{E[\lambda] - E[\lambda^2] + \rho E[\lambda^2]}{1 - E[\lambda] + \rho E[\lambda^2]}$$

and

$$\pi_1(\rho) = \frac{E[\lambda^2] - \rho E[\lambda^2]}{E[\lambda] - \rho E[\lambda^2]}.$$

Then, when a fraction ρ of type (v_H, v_H) consumers refuse to purchase good 1 and when all other types behave according to the claim, beliefs must satisfy

$$\Pr\{v_{i2} = v_H | q_{i1}\} = \pi_{q_{i1}}(\rho) \quad q_{i1} \in \{0, 1\}.$$

Next, note that $\pi_0(\rho)$ is monotone increasing with $\pi_0(0) = E[\lambda | v_1 = v_L]$ (review (6)) and $\pi_1(\rho)$ is monotone decreasing with $\pi_1(0) = E[\lambda | v_1 = v_H]$ (review (5)). Moreover, define

$$\bar{\rho} = \frac{E[\lambda^2] - (E[\lambda])^2}{E[\lambda^2]\left(1 - E[\lambda]\right)}.$$

Then, simple algebra verifies that $\bar{\rho} < 1$ and

$$\pi_0(\bar{\rho}) = E[\lambda] = \pi_1(\bar{\rho}).$$

In other words, the increasing function $\pi_0(\rho)$ crosses the decreasing function $\pi_1(\rho)$ at the point $(\bar{\rho}, E[\lambda])$ (see Figure 5). Simple algebra also verifies the following implications

$$E[\lambda] < \nu \;\Rightarrow\; \pi_0(\rho^*) < \nu = \pi_1(\rho^*), \tag{A1}$$

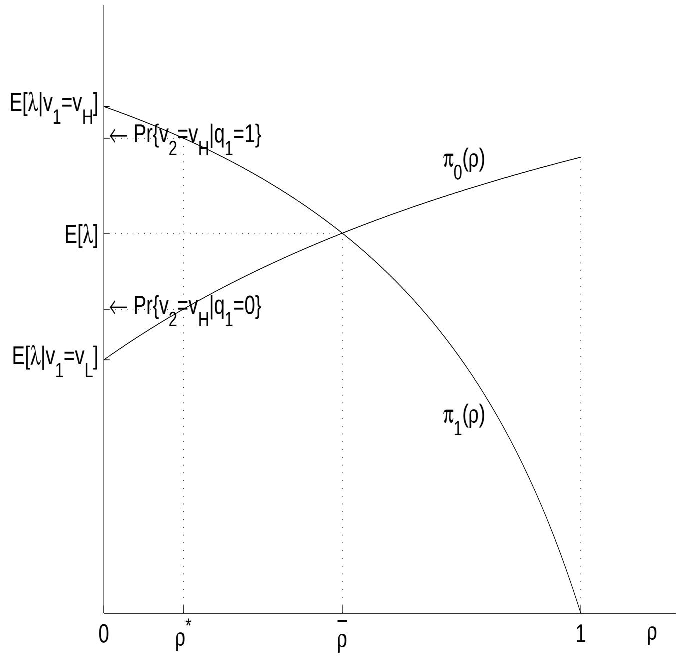
$$E[\lambda] > \nu \;\Rightarrow\; \pi_0(\rho^*) = \nu < \pi_1(\rho^*), \tag{A2}$$

and

$$E[\lambda] = \nu \;\Rightarrow\; \rho^* = \bar{\rho}. \tag{A3}$$

With all this in hand, it is finally possible to prove that a fraction ρ^* of type (v_H, v_H) consumers reject $p_1 \in (v_L, v_H)$ in any PBE.

Figure 5: Bayesian Updating



- By way of contradiction, suppose there is a PBE in which a fraction $\rho < \rho^*$ of type (v_H, v_H) consumers reject. Then

$$\pi_0(\rho) < \nu < \pi_1(\rho).$$

  Lemma (2) then requires $\phi_0 = 1$ and $\phi_1 = 0$. But, this implies

$$v_H - p_1 < (\phi_0 - \phi_1)(v_H - v_L).$$

  Lemma 5 then implies that $\rho = 1$, contrary to supposition.

- By way of contradiction, suppose there is a PBE in which a fraction $\rho > \rho^*$ of type (v_H, v_H) consumers reject. There are two cases to consider.

  (i) If $E[\lambda] \leq \nu$, then (A1) gives $\pi_1(\rho) < \nu$. Lemma 2 then requires $\phi_1 = 1$. But, this implies

$$v_H - p_1 > (\phi_0 - \phi_1)(v_H - v_L).$$

  Lemma 5 then implies that $\rho = 0$, contrary to supposition.

  (ii) If $E[\lambda] \geq \nu$, then (A2) and (A3) give $\pi_0(\rho) > \nu$. Lemma 2 then requires $\phi_0 = 0$. But, this implies

$$v_H - p_1 > (\phi_0 - \phi_1)(v_H - v_L).$$

  Lemma 5 then implies that $\rho = 0$, contrary to supposition.

5. To establish existence, suppose that firm 2's beliefs after observing the customer list are given by

$$\Pr\{v_{i2} = v_H | q_{i1}\} = \pi_{q_{i1}}(\rho^*), \quad q_{i1} \in \{0, 1\}. \tag{A4}$$

A necessary condition for a fraction ρ^* of type (v_H, v_H) consumers to refuse to buy good 1 is

$$v_H - p_1 = (\phi_0 - \phi_1)(v_H - v_L). \tag{A5}$$

Moreover, if this is satisfied, then Lemma 5 indicates that type (v_H, v_L) consumers prefer to buy good 1 and type (v_L, v_H) and (v_L, v_L) consumers prefer not to buy it. Hence, if (A5) holds and a fraction ρ^* of type (v_H, v_H) consumers refuse to buy good 1 (as they must in equilibrium), then the specified beliefs will be correct. The only question is whether values for ϕ_0 and ϕ_1 exist that satisfy (A5) and are consistent with equilibrium behavior by firm 2. There are three cases to consider.

(i) If $E[\lambda] < \nu$, then by (A1) and Lemma 2, $\phi_0 = 1$, and the value of ϕ_1 is unrestricted. Hence, (A5) is satisfied in this case *iff*

$$\phi_1 = 1 - \frac{v_H - p_1}{v_H - v_L}, \tag{A6}$$

which is feasible.

(ii) If $E[\lambda] > \nu$, then by (A2) and Lemma 2, $\phi_1 = 0$, and the value of ϕ_0 is unrestricted. Hence, (A5) is satisfied in this case *iff*

$$\phi_0 = \frac{v_H - p_1}{v_H - v_L}, \tag{A7}$$

which is feasible.

(iii) Finally, If $E[\lambda] = \nu$, then by (A3) and Lemma 2, the values of ϕ_0 and ϕ_1 are both unrestricted. Hence, (A5) is satisfied in this case *iff*

$$\phi_0 - \phi_1 = \frac{v_H - p_1}{v_H - v_L}, \tag{A8}$$

which is feasible. ■

Proof of Lemma 8

1. Suppose $p_1 = v_L$.

- to establish existence, consider the belief function

$$\Pr\{v_{i2} = v_H | q_{i1}\} = \begin{cases} E[\lambda], & \text{if } q_{i1} = 1, \\ 1, & \text{if } q_{i1} = 0. \end{cases}$$

  Given these beliefs, Lemma 2 requires $\phi_0 = 0$. But, it is then a best response for all consumers to accept because

$$v_{i1} - v_L \geq (\phi_0 - \phi_1)(v_{i2} - v_L).$$

  Also, when all consumers accept, beliefs are correct on the equilibrium path.

- To see that no other PBE of the continuation game delivers a higher expected payoff to firm 1, note that no other PBE has higher sales volume. Hence, a more profitable PBE must involve lower sales volume and positive value for the customer list. If the customer list has positive value, then either

$$\Pr\{v_{i2} = v_H | q_{i1} = 1\} < \nu < \Pr\{v_{i2} = v_H | q_{i1} = 0\} \tag{A9}$$

  or

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} < \nu < \Pr\{v_{i2} = v_H | q_{i1} = 1\}. \tag{A10}$$

(i) First, there does not exist a PBE of the continuation game with sales volume less than one satisfying (A9). To see this, suppose otherwise. Note that Lemma 2 gives $\phi_0 = 0$ and $\phi_1 = 1$. Given this, Lemma 5 indicates that only type (v_L, v_L) consumers reject because

$$v_{i1} - v_L > -(v_{i2} - v_L)$$

for all other types. But then,

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} = 0 < \nu,$$

contradicting (A9).

(ii) Next, a PBE of the continuation game with sales volume less than one satisfying (A10) does exist, but all such equilibria deliver strictly lower payoffs than v_L to firm 1. To see this, note that Lemma 2 gives $\phi_0 = 1$ and $\phi_1 = 0$. Then, Lemma 5 implies that type (v_H, v_L) consumers buy good 1 while type (v_L, v_H) consumers do not. Both type (v_H, v_H) and (v_L, v_L) consumers are indifferent about buying good 1. Let ρ be the fraction of type (v_H, v_H) consumers who do not buy good 1, and let α be the fraction of type (v_L, v_L) consumers who do buy it. Then it is straightforward to verify that so long as ρ and α are not too large, there exists a PBE with the specified purchasing pattern in which $\phi_0 = 1$ and $\phi_1 = 0$. Moreover, firm 1's payoff in such a PBE is

$$\begin{array}{ll} & \left(E[\lambda] - \rho E[\lambda^2] + \alpha\left(1 - 2E[\lambda] + E[\lambda^2]\right)\right) v_L \\ + & (1-\rho)E[\lambda^2]v_H + \left(1 - E[\lambda] + \rho E[\lambda^2] - \alpha\left(1 - 2E[\lambda] + E[\lambda^2]\right)\right) v_L \\ - \max\{v_L,\, E[\lambda]v_H\}, & \end{array}$$

where the top line is the revenue from sale of good 1 and the bottom line is the revenue from sale of the customer list. Combining terms renders this as

$$v_L + (1-\rho)E[\lambda^2]v_H - \max\{v_L,\, E[\lambda]v_H\}.$$

Simple algebra and the fact that $E[\lambda^2] < E[\lambda]$ verify that this is less than v_L.

2. Suppose $p_1 = v_H$.

- To establish existence, suppose that $\phi_0 = \phi_1$ in accordance with (A6), (A7), and (A8). Then it is a strict best response for type (v_L, v_L) and type (v_L, v_H) consumers to reject and a weak best response for type (v_H, v_L) and type (v_H, v_H) consumers to accept. Hence, there is a PBE of the continuation game in which the purchasing pattern of the consumers coincides with the one given in Lemma 7 and in which the beliefs are given in (A4).
- Proving that no other PBE of the continuation game delivers a higher expected payoff to firm 1 takes two steps. First it is shown that the customer list is worth zero in every PBE of the continuation game. Then it is shown that the PBE in question involves the highest sales volume for good 1.

  (i) To see that $\hat{W}(v_H) = 0$ in every PBE of the continuation game, suppose to the contrary that $\hat{W}(v_H) > 0$ in some PBE. In this case, either (A9) or (A10) must hold.

– If (A9) holds, then Lemma 2 gives $\phi_0 = 0$ and $\phi_1 = 1$. In this case, Lemma 5 indicates that all type (v_H, v_H) and no type (v_L, v_L) consumers purchase good 1. Given this, it is straightforward to verify that

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} \leq E[\lambda_i | v_{i1} = v_L]$$

and

$$\Pr\{v_{i2} = v_H | q_{i1} = 1\} \geq E[\lambda_i | v_{i1} = v_H\}.$$

Combining these with (7) results in a contradiction of (A9).

– If (A10) holds, then Lemma 2 gives $\phi_0 = 1$ and $\phi_1 = 0$. Given this, Lemma 5 indicates that no type (v_H, v_H), type (v_L, v_H), and type (v_L, v_L) consumers buy good 1. If no type (v_H, v_L) consumers buy it, then no updating occurs and $\hat{W}(v_H) = 0$. If a positive measure of type (v_H, v_L) consumers buy good 1, then $\Pr\{v_{i2} = v_H | q_{i1} = 1\} = 0$, contradicting (A10).

(ii) Finally, to see that no PBE of the continuation game exists with higher sales volume, suppose to the contrary that there is a PBE with sales volume greater than $E[\lambda] - \rho^* E[\lambda^2]$. Now, Lemma 5 indicates that type (v_L, v_L) consumers never accept $p_1 = v_H$ in any PBE because

$$v_L - v_H < (\phi_0 - \phi_1)(v_L - v_L), \quad \forall\ \phi_0 \text{ and } \phi_1 \in [0, 1].$$

Hence, the PBE must involve acceptance by a fraction greater than $1 - \rho^*$ of type (v_H, v_H) consumers or by more than zero type (v_L, v_H) ones. This, however, implies

$$\Pr\{v_{i2} = v_H | q_{i1} = 0\} < \nu < \Pr\{v_{i2} = v_H | q_{i1} = 1\}.$$

Condition (7) and Lemma 2 then require $\phi_0 = 1$ and $\phi_1 = 0$. But then, Lemma 5 indicates that no type (v_H, v_H) or type (v_L, v_H) consumers will buy good 1, a contradiction. ■

Proof of Proposition 3

First it is shown that firm 1 optimally posts one of two prices, $p_1 = v_L$ or $p_1 = v_H$, and that the customer list is worthless in either case. This takes three steps.

1. If firm 1 posts $p_1 > v_H$, then no consumer purchases good 1 (by Lemma 6) and the customer list is worth zero. Hence, her payoff from posting a price in this range is zero.

2. If firm 1 posts $p_1 < v_L$, then all consumers purchase good 1 (by Lemma 6), and the customer list is worth zero. Hence, her payoff from posting a price in this range is p_1. The Supremum payoff is v_L, which is attained in the equilibrium of the continuation game identified in the first part of Lemma 8. Moreover, Lemma 8 indicates that no other PBE of this continuation game delivers a higher expected payoff to firm 1.

3. If firm 1 posts $p_1 \in (v_L, v_H)$, then the purchasing pattern of the consumers coincides with the one given in Lemma 7. Moreover, (A1), (A2), and (A3) all indicate that if firm 2 purchases the customer list, then she is indifferent about practicing dynamic pricing. This implies that the customer list is worth zero. Hence, firm 1's payoff from posting $p_1 \in (v_L, v_H)$ is $(E[\lambda] - \rho^* E[\lambda^2])\, p_1$. The Supremum payoff is $(E[\lambda] - \rho^* E[\lambda^2])\, v_H$, which is attained in the equilibrium of the continuation game identified in the second part of Lemma 8. Moreover, Lemma 8 indicates that no other PBE of this continuation game delivers a higher expected payoff to firm 1.

Next, simple algebra verifies

$$\left(E[\lambda] - \rho^* E[\lambda^2]\right) v_H \leq v_L \;\Leftrightarrow\; \underline{\gamma} E[\lambda] \leq \nu.$$

The remainder of the claim then follows from Lemma 2. ■

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