Price Competition and the Use of Consumer Data

Brian C. Albrecht*

September 30, 2019

Firms have access to vasts amounts of data on consumers and potential consumers, which allows them to strategically vary prices across consumers, *i.e.* price discriminate. To study the effects of data on consumer welfare, I analyze a Bertrand duopoly model where each consumer's valuation for each firm's good is uncertain. Instead of imposing that firms have access to a specific type of data, I allow for general structures of data, where firms may have varied quality and forms of data on consumers. Fixing the data, due to the discontinuities in Bertrand competition, the unique equilibrium is only supported through price dispersion. Although solving for general price dispersion equilibria is complex, I easily construct the equilibrium by harnessing features of each firm's residual demand curve. In equilibrium, firm 1 randomizes her price and generates a unit-elastic residual demand for firm 2. A unit-elastic residual demand makes firm 2 indifferent over a range of prices and willing to randomize price. I then vary the available data and compare the welfare consequences. In the baseline case, completely public consumer data (perfect price discrimination) is *optimal* for consumers. The force of Bertrand competition for consumers who only buy from the lowest price firm—as in the standard symmetric Bertrand model—outweighs the losses of a high price for customers who strongly prefer one firm's good so that the firm can act like a monopolist. In the general case, complete consumer data is not necessarily optimal, but it is still optimal to segment the market into monopoly markets and competitive (symmetric Bertrand) markets.

JEL-Classification: D11, D43, D82, D83, L13

Keywords: Bertrand competition, price dispersion, market segmentation

*Department of Economics, University of Minnesota. Email: mail@briancalbrecht.com. Thanks to Dirk Bergemann, Keler Marku, Kevin M. Murphy, Sergio Ocampo-Diaz, and David Rahman for helpful comments and conversations. Thanks to the Institute for Humane Studies Summer Fellowship for funding support. First online draft: June 12, 2018.

1 Introduction

Technological change has given both consumers and firms access to information that was previously unimaginable. Consumers can access more data about firms and their products through online reviews. firms can access more data about consumers through deeper market research and tracking data on previous purchases, web searches, or social media posts. That consumer data is vital to a firm's ability to price discriminate.

At the same time, technological change has allowed firms to differentiate products. Identical goods from the supply side (same marginal cost) are not identical from the demand side (different marginal valuation). Gone are the days of one-size-fits-all goods (Neiman and Vavra 2019) To me, most beer tastes the exact same and is substitutable. To others, that claim is preposterous. But all beer companies need to pick prices with both types of consumers in mind. Crucially though, the degree of substitutability, and thus competition, depends on the market make-up and what firms' know about consumers. This paper asks, first, how do firms compete in a market where people differ in the degree of substitutability? Second, how does firm access to data on consumers affect how they compete? Finally, when does access to consumer data come back to help or hurt consumers?

To be more specific about the model, I study a stylized model where a continuum of consumers can buy a single good from one of two firms. The two firms compete *à la* Bertrand. However, contrary to a textbook Bertrand model with identical goods—as in Mas-Colell, Winston, and Green (1995, 388) or Tirole (1988, 310)—the consumer may have a different valuation for the goods from the two firms. A firm faces a tradeoff between raising the price when the consumer prefers its good and lowering price to compete whenever the consumer prefers the other firm's good. Therefore, I extend a standard model of price discrimination to allow for general, varied access to consumer data by firms.

The paper first considers a simple model to capture the trade-off facing firms where the consumer may be one of three types: one type loyal to each firm for whom the firms' goods are not substitutes and each firm would be a monopolist if they knew the loyal consumers and a third type for whom the firms' goods are perfect substitutes. That setup captures the fundamental trade-off. Each firm wants to raise prices on the consumers loyal to them since they are monopolists. However, for the consumers that are not loyal, the force of Bertrand competition pushes the price down.

Constructing equilibria is not obvious in this environment. In general, to balance this trade-off, the unique equilibrium involves each firm randomizing over prices. Due to the discontinuity inherent in Bertrand competition, the randomization allows each firm to avoid losing the consumer by only a small amount on price. This leads to price dispersion in equilibrium.

My first contribution is to construct the equilibrium using simple observations about the residual demand curve facing each firm and what each firm can guarantee itself by only pricing for loyal consumers.[1] The unique equilibrium on the game involves both firms choosing their price to generate a unit-elastic demand curve for the other firm, making the firms indifferent over a range.

My paper then asks in a stylized model, given the equilibrium behavior under competition, is giving firms access to consumer data helpful or harmful to consumers and producers? Without competition, the welfare implications of consumer data are clear; information which allows price discrimination weakly raises total profit. This is simply a manifestation of Blackwell (1951, 1953) that information is always valuable for single receiver.[2] Unless output increases, price discrimination lowers consumer surplus.

1. The construction of the demand curve is similar to Albrecht (2018)'s analysis of Roesler and Szentes (2017).

2. See Bergemann, Brooks, and Morris 2015 for the general information case of a monopolist.

To study the role of information, I fix underlying valuations, i.e. demand curve in the aggregate market. I then vary the consumer data available to each firm, allowing price discrimination. However, I allow for the case where firms do not have the same information. Therefore, higher order beliefs matter, e.g. Target doesn't know my exact address, *but* Target knows that Amazon knows... These beliefs affect equilibrium prices.

Finally, given the competitive pricing of the two firms, what is the consumer-optimal form of consumer data? Even in the simple example, the solution to this trade-off is not obvious. However, I show that, contrary to the monopoly case, giving firms *complete information* is consumer optimal, even in an efficient environment where trade always occurs. The increase in consumer surplus does not come from any risk-aversion or from increased consumption, as in models where price discrimination increases consumer surplus by increasing trade. Even environments where production does not increase, consumer surplus is maximized under complete information, because the firms to compete more fiercely and charge a lower price when the consumer learns the goods are substitutes for him. The gain from fierce Bertrand competition when the firm's goods are perfect substitutes outweighs the loss when the consumer learns the she only values one good and thus that firm is able to raise its price.

1.1 Related Literature

This paper contributes to the literature on the relationship between price discrimination and competition is a standard issue in industrial organization–in classic form in Pigou (1920) and Robinson (1933), and in modern form in Borenstein (1985) and Holmes (1989) (See Stole (2007) for a summary).[3] One particular branch of the price discrimination liter-

3. This literature has always included a large empirical comppnent. For a recent example, Chandra and Lederman (2018) show that in the Canadian airline market price discrimination in raises prices for some passengers and lowers prices for others. This is consistent with my main result, although in my model the average price is lower.

ature shows the optimality of constant-elasticity demand curves, which also show up in my model. This shows up in more standard monopoly models, such as Aguirre (2008), Aguirre and Cowan (2015), Roesler and Szentes (2017), and Condorelli and Szentes (2019). Unit-elastic demand also shows up in non-Bayesian monopoly models, such as Neeman 2003; Bergemann and Schlag 2008; Renou and Schlag 2010. These models involve some form of a maximin utility function or minimax regret, which relates to the outcome of my model where one firm can only achieve his maximin revenue and the rest is competed away by the other firm.

The constant-elasticity implies that there can be multiple prices where marginal revenue equals marginal cost. This leads in my model to price dispersion Contrary to the classic price discrimination papers of Stigler (1961) and Burdett and Judd (1983), in my model, price dispersion comes from *each firm* setting a random price, such as in Varian (1980). However, the market power that generates the distribution is due to the goods being imperfect substitutes, and thus having some brand loyalty as in Rosenthal (1980), compared to search frictions.

However, since each firm is randomizing over the set of prices, what Menzio and Trachter (2015) aptly call a "game of cat-and-mouse", the equilibrium prices are not only the lowest, consumer-optimal price found in Roesler and Szentes (2017), but a range of prices that the firm is indifferent between.

In addition, my paper contributes to the literature on information design. In particular, I consider the range of possible outcomes that could arise for some information structure, as in Bergemann, Brooks, and Morris (2015). In particular, I am interested in the information structures that are consumer-optimal, as in Roesler and Szentes (2017). However, contrary to both papers, I introduce competition explicitly into the model. Competition is between the receivers of information, making it more like the literature on robust mechanism design (Bergemann, Brooks, and Morris 2013), and not between the senders, which is the topic of much of the literature on information design and competition (Gentzkow and Kamenica 2016; Au and Kawai 2016; Albrecht 2017). As in Bergemann, Brooks, and Morris (2015), the consumer-optimal outcome involves extremal markets, where the firms are indifferent among all prices in the support of valuations.

2 Three Type Model

Consider a simple model with three types of consumers with a total measure of one. There are consumers who are loyal to firm 1 and only buy from firm 1. Similarly, there are consumers loyal to firm 2. Finally, there are indifferent consumers who buy from whoever has the cheapest price. Each consumer has with unit demand at $p = 1$ from the firm(s) it is willing to buy from.

A market for firm i is the collection of consumers that a firm cannot differentiate and must set the same price for. Mathematically, a market is defined as a distribution of the types of consumers. Graphically, a market is a point on the unit simplex. For all illustrations, I will consider a starting, aggregate market: $\left(\frac{1}{4}, \frac{1}{6}, \frac{7}{12}\right)$. The aggregate market with no price discrimination is represented by the orange circle in Figure 1.

If both firms have complete data on consumers, they can segment consumers into three markets and perfectly price discriminate. For the example, there is one market $(1, 0, 0)$ with measure $\frac{1}{4}$, another market $(0, 1, 0)$ with measure $\frac{1}{6}$, and a final market $(0, 0, 1)$ with measure $\frac{7}{12}$. These three markets are represented by the blue diamonds in Figure 1.

Those two examples are extreme. There are other types of markets. Consider a situation where each firm receives a signal that with probability q correctly reveals a consumers type and with probability $(1 - q)$ the signal comes a random consumer. This nests the two previous cases with $q = 1$ being a perfect signal and $q = 0$ being an uninformative signal.

Figure 1: Feasible Markets

For any intermediate q, upon seeing a signal that says "this consumer is an indifferent type" the firm properly updates and puts more weight that the consumer being indifferent. With this set of three possible signals, there are three markets: one corresponding to each signal. On the simplex, each market corresponds to a convex combination of the aggregate market and the perfectly discriminated markets. The three markets for are plotted by the green triangles in Figure 1.

More formally, there are two firms with differentiated goods that cost 0 to produce. There is a continuum of non-strategic consumers; each have unit demand for total consumption. A consumer's type is a pair of valuations (willingness to pay) $v = (v_1, v_2) \in \{(1,0), (0,1), (1,1)\} = V$. Later on we will expand the set of possible valuations. The firms start with a common prior on the market: (m_{10}, m_{01}, m_{11}).

The firms' access to consumer data, also called their information structure, is a set of signals for each firm S_i, and a probability distribution which maps the profile of the consumer's values to the profile of signals: $\pi : V \to \Delta(S)$. The utility functions and the information structure (S, π) are the parameters for a game of incomplete information. We will define the rest of the game fixing (S, π).

Each firm i observes a signal $s_i \in S_i$. A pure strategy for firm i is a price $\{p_i\}_{s_i} \in \mathbb{R}_+^{|S_i|}$. The discontinuity of payoffs requires that we work with mixed prices for each firm, sometimes called price dispersion. A mixed strategy, $F_i(p|s_i)$, is the probability that $p_i \leq p$ given receiving a signal s_i. Let $f_i(p|s_i)$ be the density associated with F_i, when it is defined.

A strategy profile is a Bayes Nash equilibrium (BNE) if $f_i(p_i|s_i) > 0$ implies

$$p_i \in \arg\max_{p_i'} \quad p_i' \underbrace{\mathbb{E}[v_i = 1, v_j = 0|s_i]}_{\text{Loyal}} + p_i' \underbrace{\mathbb{E}\left[\left(1 - F_j(p_i)\right), v_i = 1, v_j = 1|s_i\right]}_{\text{Indifferent,}}$$

given $F_j(p)$, for all s_i, s_j, i, j. Because we are interested in the effect of information on equilibria, we will be doing comparative statics with respect to the information structure. In addition, we will want to ask if there exists any information structure that generates an equilibrium outcome. For that, the following definition is helpful: a strategy profile is a Bayes correlated equilibrium (BCE) if it is a BNE for some information structure (Bergemann and Morris 2016). When looking for the highest possible consumer surplus, the problem requires searching over the set of Bayes correlated equilibria.

2.1 Solving for Equilibrium, Public Consumer Data

Before looking at the set of possible information structures, it is helpful to characterize the equilibrium for particular information structures. First, we will consider public information where both firms have the same data on consumers. The easiest case is complete information, where firms receive a signal that is perfectly reveals the consumers type: $s_1 = s_2 = v$. If the consumer will not buy from the competitor, $v_i = 0$, firm j sets monopoly price of 1. If the consumer values both goods, $v_1 = v_2 = 1$, because of Bertrand competitive, the price of driven to 0. Combined, the expected price is $m_{10} + m_{01}$. If we plot the distribution of prices the expected price is the area above price distribution.

The equilibrium for the aggregate market, with no additional consumer data and therefore no price discrimination, is more complicated to solved for. Proposition 1 characterizes it.

Proposition 1. *Let $m_{10} \geq m_{01}$. The unique BNE profit is m_{10} for firm 1 and $\frac{m_{10}}{m_{10}+m_{11}}(1 - m_{10})$ for firm 2. The unique strategies are given by*

$$F_1^*(p) = \begin{cases} 0 & p < \underline{p} \\ 1 - \dfrac{\underline{p}(m_{11} + m_{01}) - pm_{01}}{pm_{11}} & p \in \left[\underline{p}, 1\right) \\ 1 & p \geq 1 \end{cases}$$

$$F_2^*(p) = \begin{cases} 0 & p < \underline{p} \\ 1 - \dfrac{m_{10}(1-p)}{pm_{11}} & p \in \left[\underline{p}, 1\right], \end{cases}$$

Proof. First, let us plot the proposed equilibrium distribution of prices in Figure 2.

Conditional on $v_1 = 1$, firm 1 assigns probability $\frac{m_{10}}{m_{10}+m_{11}}$ to being the monopolist. Regardless of what firm 2 does, firm 1 will never set a price below $\underline{p} = \frac{m_{10}}{m_{10}+m_{11}}$. Therefore, neither will firm 2.

The rest of the construction relies on simple observations of the each firm's best-response when facing a residual demand curve. Translating demand curves into game-theoretic terms, best-responding by each seller means choosing a price and quantity subject to the constraint that the pair is on her demand curve.[4] To find the best-response, plot

4. The best-response could also be found by constructing the marginal revenue (MR) curve. However, because MR is discontinuous, the optimal expected quantity is the maximum quantity such that MR > MC = 0, instead of the standard MR=MC condition used for continuous functions.

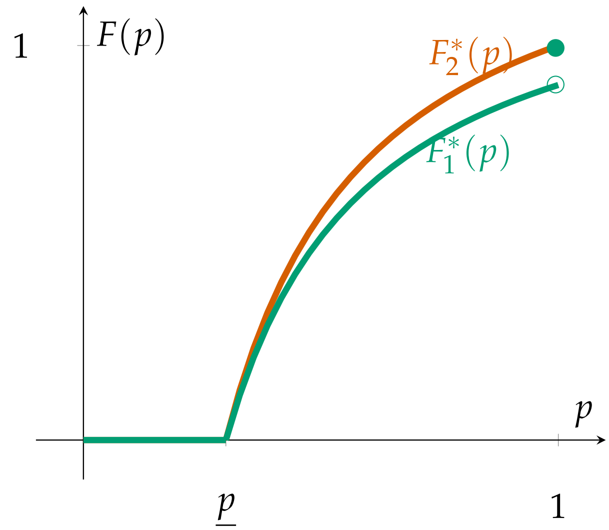


Figure 2: Equilibrium Price Distribution

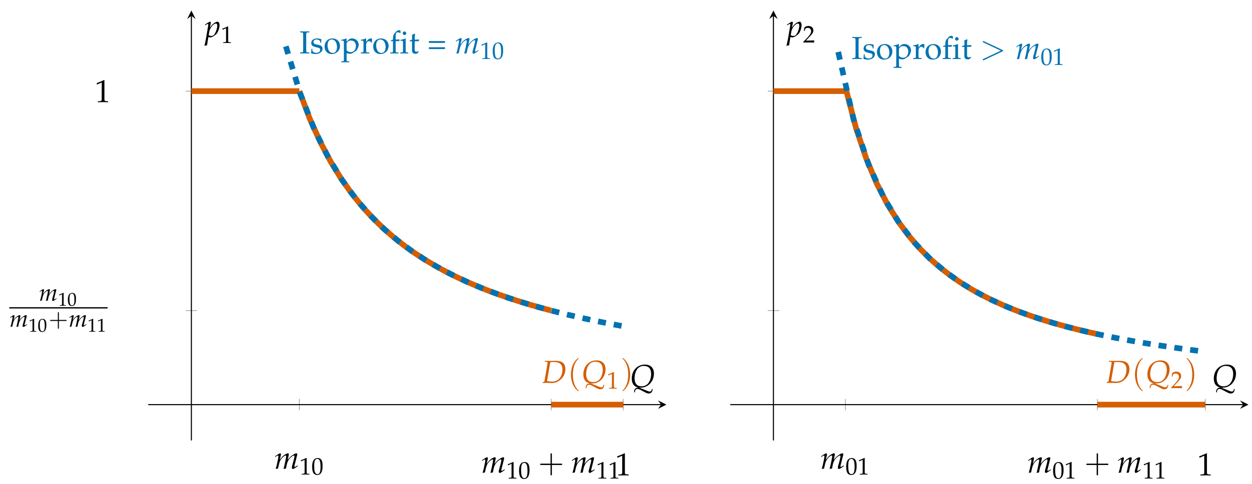
seller 1's indifference curves, which are just the iso-revenue curves, since cost is zero.[5] This is also the worst-case (maximin) profit for seller 1, since he could never do worse than if $p_2 = 0$.

To show this strategy is an equilibrium, in orange in Figure 3a, I plot firm 1's residual demand, given $F_2^*(p)$, $D(Q_1)$. Notice that to the right of m_{10}, where the residual demand comes from the indifferent buyer, the curve is simply one minus the $F_2^*(p)$ of seller 2's randomized price. The only complication is a specific price is set with positive probability. Firm 1's problem is to maximize profits, subject to its residual demand curve. Because marginal cost is zero, the isoprofit curves are simply given by $\pi = p_1 Q_1$.

Because of the shape of the residual demand curve, firm 1 is indifferent between any price between $\frac{m_{10}}{m_{10}+m_{11}}$ and 1. Therefore, firm 1 would be optimally mixing with any price in that range. For any mixing, the highest profit is simply given by m_{10}.

We do the same thing for firm 2 in Figure 3b. Again, firm 1 has picked a strategy However, this time, since firm 1 set $p = 1$, the top of firm 2's residual demand extends

5. It likely exists, but I have not seen indifference curves plotted in Marshallian, quantity-price coordinates in writing. I thank Kevin M. Murphy for pointing out this tool.



(a) Firm 1

(b) Firm 2

Figure 3: Residual Demand

out beyond just it's loyal consumers with measure m_{01} and firm 2 can still receives some consumers when $p_1 = 1$.

Therefore, we have showed that each strategy is a best response to the other strategy and constructed an equilibrium. Uniqueness is immediate as well. ■

Due to the discontinuity of payoffs in Bertrand competition, if $p \neq 1$, every equilibrium involves a distribution of prices. For either firm to be indifferent, $p \times Q =$ constant. The distribution of prices is therefore proportional to $-\frac{1}{p}$. The only exception is that there could be a with possible mass point at $p = 1$. This distribution will show up in any equilibrium.

Let us consider the construction of the equilibrium, as compared to its verification in the proof, because this construction can be applied to a wide range of markets. Translating demand curves into game-theoretic terms, best-responding by each seller means choosing a price and quantity subject to the constraint that the pair is on her demand curve. As a first "guess" of an equilibrium strategy, let us first find firm 1's maximin strategy; suppose that $p_2 = 0$. The best-response price is one and the expected quantity that seller 1 sells is

m_{10}.[6]

However, setting a price of zero is not optimal for seller 2. Now I ask, what is the highest pure strategy price that seller 2 can charge without changing one's behavior? That case is clearly a better-reply, even if it is not a best-reply. Increasing the price of seller 2 increases seller 1's demand curve over the range $(m_{10}, m_{10} + m_{11})$ (selling to the indifferent types), by p_2. By plotting seller 1's iso-revenue curve, we can see that seller 2's price can be increased to $\frac{m_{10}}{m_{10}+m_{11}}$ without inducing seller 1 to change. While this is not going to be an equilibrium, it will allow us to bound prices. First, it shows that it is never a best-response for seller 2 to set a price lower than $\underline{p}$. She can raise her price to $\underline{p}$ while one is still best-responding with her price of one. It also creates a lower bound for seller 1's price. Even if seller 1 sold every time the buyer was not loyal to the seller 2, $Q_1 = m_{10} + m_{11}$, she would still make less profit for any price below $\underline{p}$ than if she just set a price of one. Therefore, both sellers will never drop their price below $\underline{p}$ in any equilibrium.

Seller 2 can still do better by randomizing between $\underline{p}$ and one. This is like setting a non-linear price and induces a residual demand curve for seller 1 that is no longer flat in the middle.[7] The demand curve varies with the cumulative distribution of seller 2's randomized strategy. Again, the demand curve for seller is the price set by seller 2, but now in a probabilistic sense. The residual demand curve for the indifferent buyer is simply one minus the CDF of seller 2's randomized price. The only complication is a specific price is set with positive probability. Better-replying by seller 2 With randomization means increasing seller 1's demand curve for all prices between $\underline{p}$ and one such that seller 1 is still indifferent. Figure 3a shows the demand curve where seller 1 is indifferent between a

6. The best-response could also be found by constructing the marginal revenue (MR) curve. However, because MR is discontinuous, the optimal expected quantity is the maximum quantity such that MR > MC = 0, instead of the standard MR=MC condition used for continuous functions.

7. Using the indifference curve to trace out the optimal policy resembles one construction of the optimal income tax rate in an optimal income tax model, like Mirrlees (1971).

range of prices, which is generate by a particular pricing strategy. This pricing strategy is also seller 2's equilibrium pricing strategy, as explain in Proposition 1.[8]

However, even with all of this mixing, neither can achieve more in equilibrium than winning their respective market with $\underline{p}$. The randomization protects against undercutting by the other seller but in equilibrium does not generate any addition profit, resembling the normal Bertrand force that drives profits to zero.[9]

Notice that the process above for finding equilibrium is the standard way of solving for a mixed-strategy equilibrium but just applied to a supply and demand setting with a continuum of prices. The same approach can be applied to finding the randomization by seller 1 to make seller 2 indifferent. However, seller 2's guarantee is pinned down by pricing at $\underline{p}$.

This process of finding the mixed strategy is standard. We search for the strategy of firm 1 that makes firm 2 indifferent (willing to mix) and vice versa. But we are looking for a mixed strategy over a continuum, so it is not immediately easy to visually. That is where the residual demand curves come in. The demand curves immediately allow the economist to picture a continuous variable in a natural way.

It is worth pointing out a corollary of the above proposition.

Corollary 1. *1) Consumer surplus under perfect price discrimination is weakly higher than consumer surplus under no price discrimination. 2) Producer surplus under perfect price discrimination is weakly lower than producer surplus under no price discrimination. 3) The relationships are strict if* $m_{10} \neq m_{01}$.

8. If the parties are symmetric ($m_{01} = m_{10}$), each seller receives her loyal customers and we are back to perfect competition, where each person receives her marginal product (Ostroy 1984), as is standard for symmetric Bertrand competition.

9. This also resembles matching pennies or the information design model in Albrecht (2017), where there is political competition with discontinuities and randomization prevents the other party from winning. However, randomization does little to the odds of winning in equilibrium. Both matching pennies and political competition are zero-sum games. With this is technically not zero-sum, it shares some characteristics.

Corollary 1 says, no matter the distribution of types, complete data on consumers is always better than no data on consumers. The

Notice that we have already done the work to solve the general model of public information. The fact that this is the "aggregate" market is not important. The equilibrium price distributions will be the same, if the market was the result of some consumer data signal. Therefore, we can immediately plot the expected price for any market in the simplex, using the heat map of Figure 5.

In addition, we can search for the buyer optimal (lowest expected price) and seller optimal (highest expected price) information structures. The optimal convex combinations are presented by the lines on Figure 5. Proposition 2 proves that complete information is consumer optimal.

Proposition 2. *Consumer surplus is maximized under perfect price discrimination.*

Proof. Bayes' Law only restricts the new distributions of types to sum to the prior. Therefore, we can maximize/minimize over all feasible distributions by "concavification"(Kamenica and Gentzkow 2011).

To better visualize and use the concavification approach, consider three cross sections of the expected price, one at the left edge, where $m_{01} = 0$, one in the middle, where $m_{10} = m_{01}$, and one at the right edge, where $m_{10} = 0$. The total profit is plotted in green and is a convex function.

The profit minimizing, and therefore consumer surplus maximizing, is given by the concave envelope on the function. Because the total profit is convex, the concave envelope touches the convex function at the extreme point: $(1, 0, 0), (0, 1, 0), (0, 0, 1)$.

Therefore, we have shown that complete information is optimal for consumers. ■

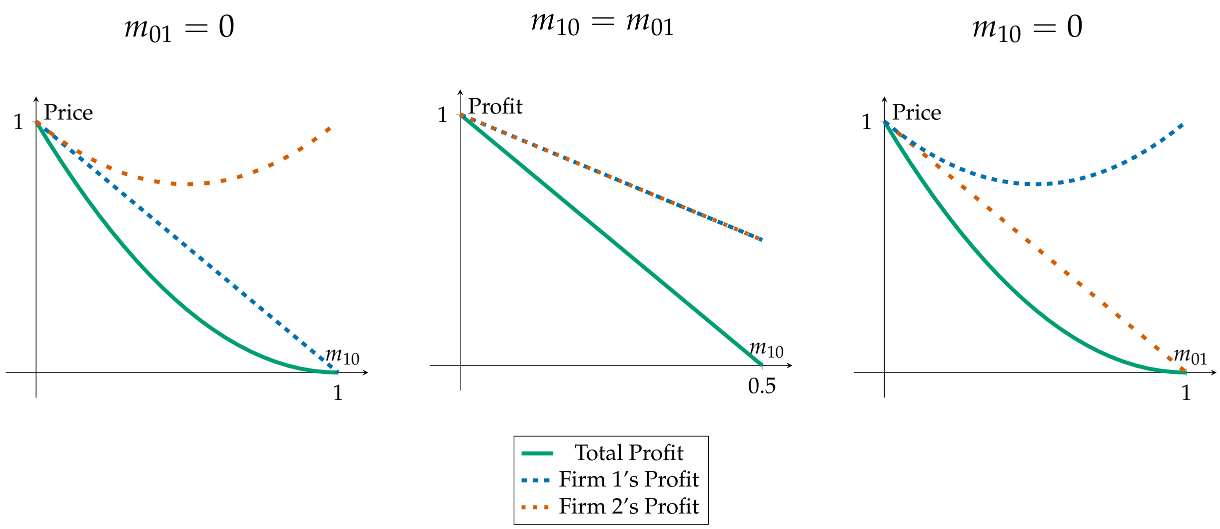


Figure 4: Profit Cross-sections

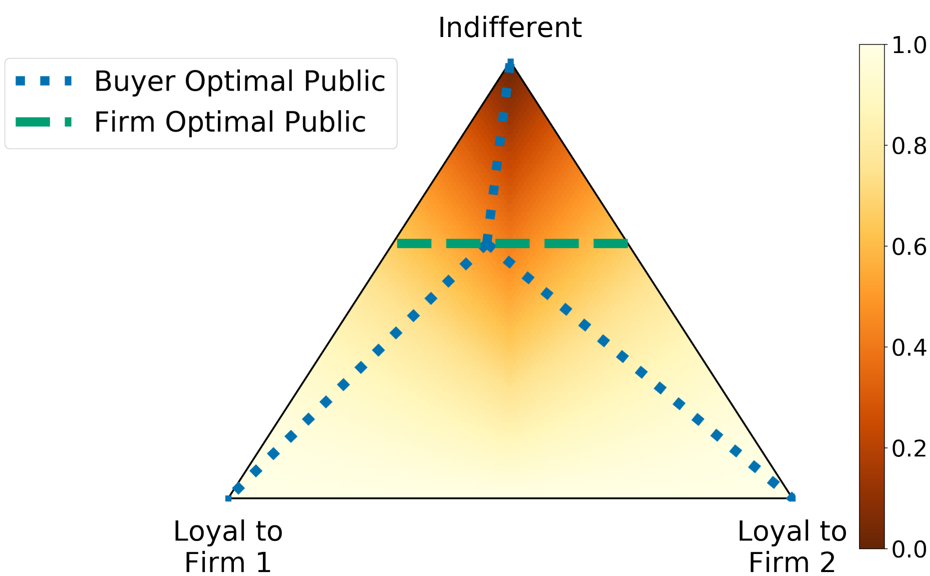


Figure 5: Expected Price for a Market

2.2 Asymmetric Consumer Data

Most models of market competition assume firms have symmetric information, as above. However, I am a different person according to Amazon vs. Target. Amazon knows that I am a South Minneapolis male who buys too many economics books. Target only knows that I am a person shopping in Minneapolis on Tuesday. However, pricing strategies will still be related; Target still needs to consider Amazon's pricing.

To understand this type of asymmetric consumer data, let us consider a simple case where firm 1 has complete information and firm 2 has only aggregate information. Again, each market for a firm is a point on the simplex.

However, now higher order beliefs matter. There is no longer an objective "market", just overlapping markets. Firm 2 knows that firm 1 knows the true type. Firm 2 only needs to consider competition from firm 1 when the true type is indifferent. For pricing, firm 2's relevant market is made of itsloyal consumers and indifferent. The markets are be plotted in Figure 6.

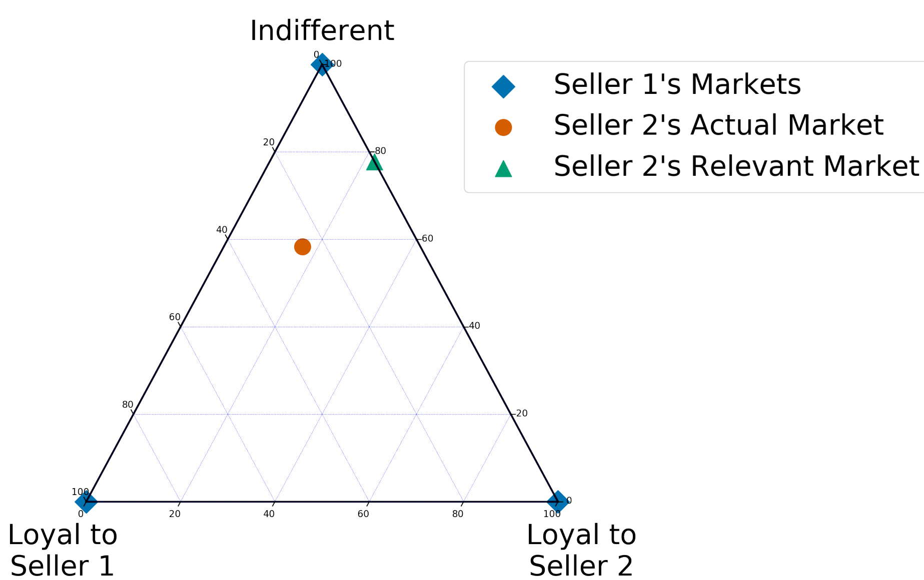


Figure 6: Overlapping Markets

It is easy to show that, relative to no consumer data, consumer data that allows perfect price discriminate by firm i, strictly increases firm i's profit, strictly decreases firm j's, and can increase or decreases total producer profit.

In general, overlapping markets can be much more complex. They can really on correlated information, where the signal that firm i receives is correlated with the signal that firm j receives.

While more public consumer data always leads to lower expected prices, this is not true for private information. The following proposition shows that the worst case for consumers is correlated data, which effectively allows the firms to collude and avoid Bertrand competition.

Proposition 3. *There exists a structure correlated consumer data that maximizes prices and minimizes consumer surplus.*

Proof. I will construct the buyer's worst-case information structure, even though the proposition simply says exists. Imagine an information designer who reveals consumer data to the firms and recommends an incentive compatible price. The designer commits the following information for the indifferent consumers, only partially revealing the indifferent consumers.

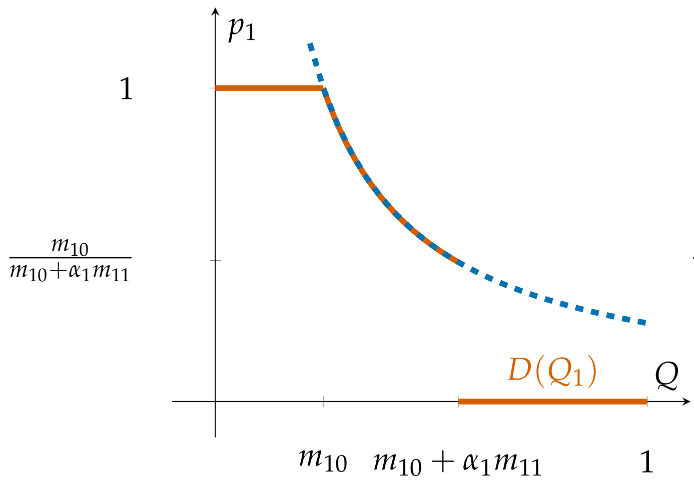
	Reveal	Do Not
Reveal	0	α_1
Do Not	α_2	$1 - \alpha_1 - \alpha_2$

The designer recommends $p = 1$ when a firm sees no signal and recommends a corresponding mixed distribution when it is revealed the firm is indifferent.

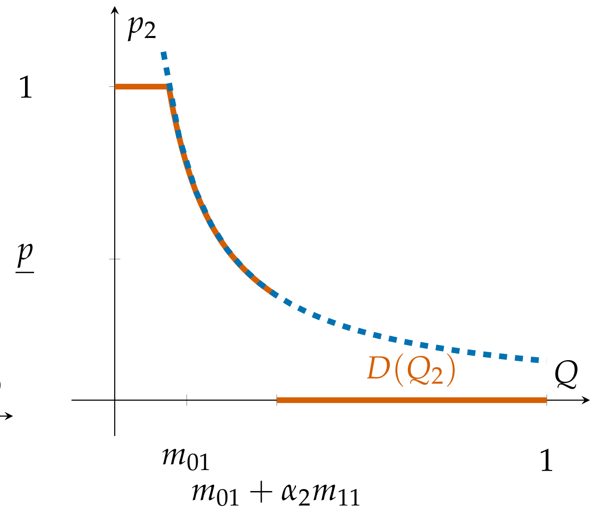
Consider the problem when firm 1 receives no signal. How high can firm 2's prices go?

■

With all of these cases solved for, we can now plot the distribution of equilibrium prices for the six cases in Figure 8. The expected price and profit is the area above the



(a) Firm 1



(b) Firm 2

Figure 7: Residual Demand

distribution. Therefore, consumer surplus is the area under the distribution. The vector of surplus for each case is plotted in Figure 9

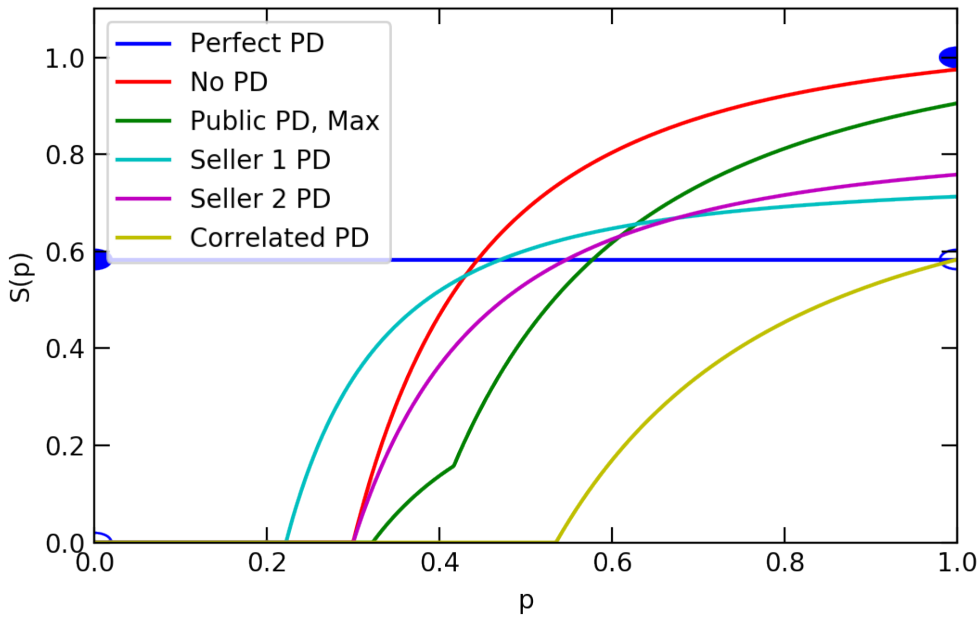


Figure 8: Price Distribution

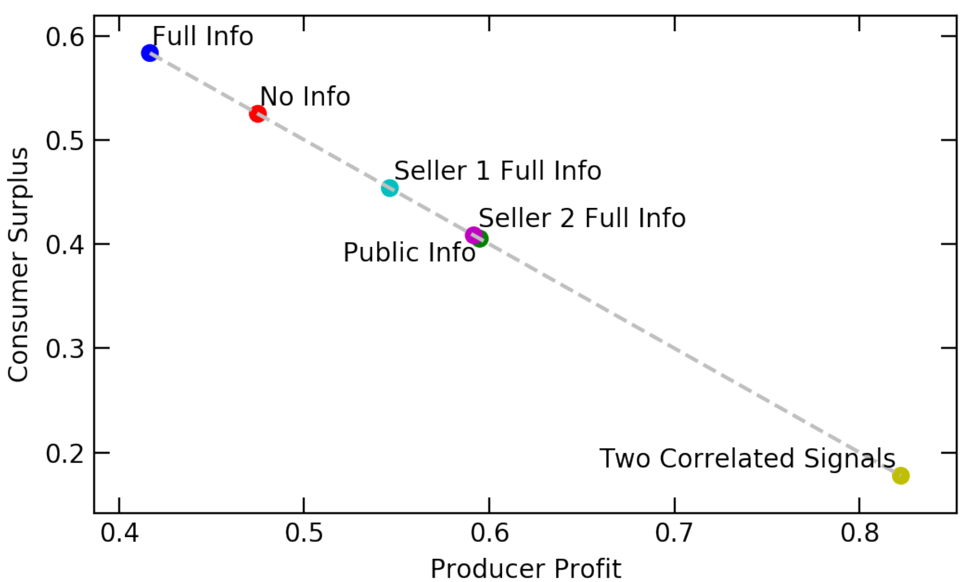


Figure 9: Surplus Division

3 Conclusion

This paper studies a version of Bertrand competition where firms may have access to more detailed consumer data. In equilibrium, each firm chooses a strategy which is a distribution of strategies that induces a unit-elastic residual demand curve for the other firm. This makes each firm indifferent over a range of prices and ensures an equilibrium, given some uncertainty.

I then analyze the welfare consequences of the consumer and duopolists having additional information about the consumer's tastes. With additional information, the firms can use that information to set different pricing strategies, i.e. use third-degree price discrimination. I solve for the consumer-optimal information structure: completely revealing data. While firms are able to use data are able to raise price above marginal cost and thus exploit their market power through price discrimination when the consumer prefers one good, complete information unleashes the power of competition when firms must ruthlessly compete on price. Competition works best in full light.

References

Aguirre, Iñaki. 2008. "Output and misallocation effects in monopolistic third-degree price discrimination." *Economics Bulletin* 4 (11): 1–11. (Cited on page 5).

Aguirre, Iñaki, and Simon G. Cowan. 2015. "Monopoly price discrimination with constant elasticity demand." *Economic Theory Bulletin* 3, no. 2 (October): 329–340. doi:10.1007/s40505-014-0063-3. http://link.springer.com/10.1007/s40505-014-0063-3. (Cited on page 5).

Albrecht, Brian C. 2017. "Political Persuasion." https://briancalbrecht.github.io/albrecht-political-persuasion.pdf. (Cited on pages 6, 13).

———. 2018. "Some Price Theory of Buyer-Optimal Learning." (Cited on page 3).

Au, Pak Hung, and Keiichi Kawai. 2016. "Competition in Information Disclosure." (Cited on page 6).

Bergemann, Dirk, Benjamin Brooks, and Stephen Morris. 2013. "Extremal Information Structures in the First Price Auction." (Cited on page 5).

———. 2015. "The Limits of Price Discrimination." *The American Economic Review* 105 (3): 921–957. ISSN: 00028282. doi:10.1257/aer.20130848. http://dx.doi.org/10.1257/aer.20130848. (Cited on pages 3, 5, 6).

Bergemann, Dirk, and Stephen Morris. 2016. "Bayes correlated equilibrium and the comparison of information structures in games." *Theoretical Economics* 11 (2): 487–522. ISSN: 19336837. doi:10.3982/TE1808. http://doi.wiley.com/10.3982/TE1808. (Cited on page 8).

Bergemann, Dirk, and Karl H. Schlag. 2008. "Pricing without Priors." *Journal of the European Economic Association* 63 (2): 560–569. http://www.jstor.org/stable/40282665. (Cited on page 5).

Blackwell, David. 1951. "Comparison of Experiments." In *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability,* edited by Jerzy Neyman, 93–102. Berkeley: University of California Press. (Cited on page 3).

———. 1953. "Equivalent Comparisons of Experiments." *The Annals of Mathematical Statistics* 24 (2): 265–272. doi:10.2307/2236332. http://www.jstor.org/stable/2236332. (Cited on page 3).

Borenstein, Severin. 1985. "Price discrimination in free-entry markets." *Rand Journal of Economics* 16 (3): 380–397. (Cited on page 4).

Burdett, Kenneth, and Kenneth L. Judd. 1983. "Equilibrium Price Dispersion." *Econometrica* 51 (4): 955–969. http://www.jstor.org/stable/1912045. (Cited on page 5).

Chandra, Ambarish, and Mara Lederman. 2018. "Revisiting the Relationship between Competition and Price Discrimination." *American Economic Journal: Microeconomics* 10 (2): 190–224. doi:10.1257/mic.20160252. https://doi.org/10.1257/mic.20160252. (Cited on page 4).

Condorelli, Daniele, and Balazs Szentes. 2019. "Information Design in the Hold-up Problem." *Journal of Political Economy.* http://personal.lse.ac.uk/szentes/docs/holdup.pdf. (Cited on page 5).

Gentzkow, Matthew, and Emir Kamenica. 2016. "Competition in Persuasion." *Review of Economic Studies* 84, no. 1 (January): 300–322. ISSN: 1467937X. doi:10.1093/restud/rdw052. (Cited on page 6).

Holmes, Thomas J. 1989. "The Effects of Third-Degree Price Discrimination in Oligopoly." *The American Economic Review* 79:244–250. doi:10.2307/1804785. https://www.jstor.org/stable/1804785. (Cited on page 4).

Kamenica, Emir, and Matthew Gentzkow. 2011. "Bayesian Persuasion." *The American Economic Review* 101 (6): 2590–2615. doi:10.1257/aer.101.6.2590. (Cited on page 14).

Mas-Colell, Andreu, Michael D. Winston, and Jerry R. Green. 1995. *Microeconomic Theory.* 977. New York: Oxford University Press. ISBN: 0-19-510268-1. (Cited on page 2).

Menzio, Guido, and Nicholas Trachter. 2015. "Equilibrium price dispersion with sequential search." *Journal of Economic Theory* 160 (December): 188–215. doi:10.1016/J.JET.2015.09.004. (Cited on page 5).

Mirrlees, James A. 1971. "An Exploration in the Theory of Optimum Income Taxation." *The Review of Economic Studies* 38 (2): 175–208. http://www.jstor.org/stable/2296779. (Cited on page 12).

Neeman, Zvika. 2003. "The effectiveness of English auctions." *Games and Economic Behavior* 43, no. 2 (May): 214–238. doi:10.1016/S0899-8256(03)00005-8. https://www-sciencedirect-com.ezp1.lib.umn.edu/science/article/pii/S0899825603000058. (Cited on page 5).

Neiman, Brent, and Joseph Vavra. 2019. "The Rise of Niche Consumption." Cambridge, MA, August. doi:10.3386/w26134. http://www.nber.org/papers/w26134.pdf. (Cited on page 2).

Ostroy, Joseph M. 1984. "A Reformulation of the Marginal Productivity Theory of Distribution." *Econometrica* 52 (3): 599–630. (Cited on page 13).

Pigou, Arthur Cecil. 1920. *The Economics of Welfare.* 4th Editio. London: Macmillan. 1932. (Cited on page 4).

Renou, Ludovic, and Karl H. Schlag. 2010. "Minimax regret and strategic uncertainty." *Journal of Economic Theory* 145, no. 1 (January): 264–286. doi:10.1016/J.JET.2009.07.005. https://www-sciencedirect-com.ezp1.lib.umn.edu/science/article/pii/S0022053109001070. (Cited on page 5).

Robinson, Joan. 1933. *The Economics of Imperfect Competition.* London: Macmillan. (Cited on page 4).

Roesler, Anne-Katrin, and Balazs Szentes. 2017. "Buyer-Optimal Learning and Monopoly Pricing." *The American Economic Review* 107 (7): 2072–2080. doi:10.1257/aer.20160145. (Cited on pages 3, 5).

Rosenthal, Robert W. 1980. "A Model in which an Increase in the Number of Sellers Leads to a Higher Price." *Econometrica* 48, no. 6 (September): 1575. doi:10.2307/1912828. (Cited on page 5).

Stigler, George J. 1961. "The Economics of Information." *Journal of Political Economy* 69 (3): 213–225. (Cited on page 5).

Stole, Lars A. 2007. "Price Discrimination and Competition." Chap. 34 in *Handbook of Industrial Organization*, edited by Mark Amstrong and Rob Porter, 3:2221–2299. Amsterdam: Elsevier. ISBN: 9780444824356. doi:10.1016/S1573-448X(06)03034-2. (Cited on page 4).

Tirole, Jean. 1988. *The Theory of Industrial Organization.* MIT Press. (Cited on page 2).

Varian, Hal R. 1980. "A Model of Sales." *The American Economic Review* 70 (4): 651–659. http://www.jstor.org/stable/1803562. (Cited on page 5).