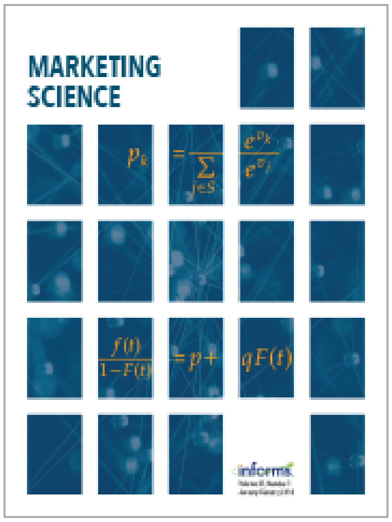

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Class Pricing

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A contract with K-class pricing divides a large set of goods or services into K classes and assigns a single price to any element of a class. While the literature has emphasized rationales based on screening, this paper looks at the implications of costly pricing. My analysis suggests that class pricing is more likely to be used when the number of buyers is smaller, the number of versions is larger, the variance in costs is smaller, and demand ex ante differs less between versions. Under simple conditions classes should be designed to minimize the sum of squared within-class cost deviations. In bilateral trades, the most efficient game form is that in which classes are designed by the player with fewer varied gains from trade, while the traded version is chosen by the other player. Decisions are thus made by the player who cares most about them, while the opponent prescribes a set of limits.

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1. Introduction

The 5 and 10 stores of yesteryear and today's many Dollar stores are examples of pricing formats in which all products are sold at a single price. Other retailers use the format for subsets of products: Used car dealers will offer *any of these for $99 a month*, Jelly Beans are sold by weight independent of flavor, and a fast-food hamburger can include any number of napkins and condiments picked up by the guest. Use of this pricing format is particularly widespread in markets for services: College tuition does not depend on the courses taken by the student, a haircut can be as the customer likes it, a stay at an all inclusive resort may take an infinite number of forms, and employees will perform any of a large set of tasks as requested by their bosses. There are also examples in which the seller is given the discretion. For example, a food-service contractor may use a large number of vegetables to satisfy a seasonal vegetables clause in a contract.

The above are examples of what we will call *one-class pricing*. Intuitively, because it is absurdly expensive to determine a price for each of the possible versions of the goods (or services) mentioned, one player (often the seller) groups the versions into a class, a single price applies to all elements in the class, and another player decides which is traded. More generally we can think about *K-class* pricing in which the versions are grouped into K classes with K different prices.

Since Mussa and Rosen (1978), the literature has explained class pricing as a response to screening problems. This paper offers a different and much simpler rationale. Based on the assumption that pricing is costly, I make predictions about the determinants of class prices, the number of classes used, how versions are grouped into classes, and who should design the classes. First, and not surprisingly, class prices are increasing in average class costs and demands. Second, fewer classes are used when precise pricing has lower benefits and/or higher costs. This is the case when the number of buyers is smaller, the number of versions is larger, the variance in costs is smaller, and demand ex ante differs less between versions. Third, sellers will define classes by cost/demand-intervals: If one high and one low cost/demand version are in the same class, then all versions with intermediate cost/demand will be included. In a simple but natural case, we find that the profit maximizing class intervals are those that minimize the sum of squared within-class cost deviations (holding the number of classes constant). Fourth, while costly pricing in general makes it more efficient for the thinner side of any market to set prices, there are also informational concerns. For the simple case of bilateral trades, it is most efficient if the classes are designed by the player with fewer varied gains from trade, while the traded versions are chosen by the other player. The ultimate decision right is given to the player who cares the most, but the opponent can constrain the amount of discretion yielded.

Throughout the paper, I take as a premise that pricing costs are subject to economies of scale, such that the cost of assigning a single price to a class of versions is lower than the cost of pricing all the versions one by one. Because the majority of economic models are based on the assumption that pricing is free in the first place, my premise rests on controversial grounds. At issue is not whether pricing is completely costless, but whether these costs are large enough to have important implications. The paper addresses this underlying controversy by assuming that pricing is costly, and deriving some implications from that.

Having provisionally accepted that pricing is costly, it is natural to assume that these costs are subject to economies of scale, at least in markets where prices are posted. Depending on the source of bargaining costs, economies of scale may be less clear if prices are arrived at through bargaining, particularly as one could imagine that players would tolerate costs in proportion to stakes. However, most people will find it plausible that a single \$30,000 deal could be negotiated in less time than thirty \$1,000 deals.

1.1. Literature

In the seventy years since Coase argued that "there is a cost of using the price mechanism" (1937, p. 390), the literature has identified several such costs. However, instead of focusing on common costs, there has been a preference for large costs, such as the threat of hold up. As suggested by the examples in the Introduction, class pricing is a widely observed phenomenon, but one of Cents rather than Dollars. Any convincing explanation must rely on what has been called the "mundane" (Williamson 1985, p. 105) costs of pricing i.e., the common but small costs associated with any price determination process, such as bargaining or take-it-or-leave-it offers.

In the broader economics literature, the most important use of common but small pricing costs in macroeconomics works on dynamic implications of menu costs (Mankiw 1985). The general idea is that pricing costs lead to sticky prices and that the resulting incomplete equilibration can provide a microfoundation for Keynesian macroeconomics (Blinder et al. 1998). Thus, the literature seeks to explain why prices are coarse over time, rather than across products, which is the focus of this paper.

The optimality of cross-sectional class pricing has received significant attention in the context of screening models where it is often optimal to bunch several types into the same contract (Mussa and Rosen 1978). There has been much less work justifying the phenomenon by the costs of detailed pricing. To the best of my knowledge, Seim and Viard (2006) and Wernerfelt (1997) are the only two papers to do so, and then only in rather narrow contexts.

Outside the academic literature, the U.S. Supreme court has used pricing costs in a ruling about license fees. The American Society of Composers, Authors and Publishers, which licenses the work of individual artists in the music industry, charges a blanket fee to bars, radio stations, etc. When the Columbia Broadcast System challenged this practice, the court found in favor of the defendant, arguing that "A middle man with a blanket license was an obvious necessity if the thousands of individual negotiations, a virtual impossibility, were to be avoided" (Broadcast Music Inc. versus Columbia Broadcast System 1978, p. 20).

At a more abstract level, characterization of the optimal composition of pricing classes allows me to minimize the same function as that minimized in a commonly used computer science algorithm for optimal quantization (Gersho and Gray 1991) as well as in the statistical technique used in *k-means* clustering algorithms (MacQueen 1967).

1.2. Plan of the Paper

Because the cost of pricing is the controversial premise of the argument, §2 is devoted to a discussion of the nature of these costs. The optimal classes and their determinants are characterized in §3, while §4 considers whether classes should be designed by sellers or buyers. The paper ends with a brief discussion in §5.

2. The Costs of Pricing

Arguments about pricing costs are often objected to with proposals to use alternative trading mechanisms. Because no single class of pricing costs, such as those incurred in connection with bargaining or signage, apply convincingly to all ways of determining prices, the players can avoid any specific problem by using some other mechanism.

This paper offers a four-pronged counterargument. First, there are many types of pricing costs and the argument does not depend on the importance of any one type. Second, while the existence of mechanisms without pricing costs is theoretically possible, widely used practices, such as bargaining and take-it-or-leave-it (i.e., posted) offers, arguably entail several important types of pricing costs. Whatever the reasons for their use, the prevalence of these mechanisms makes it important to study the implications of the associated pricing costs. Third, and perhaps more speculatively, the existence of a cost-free mechanism is immaterial unless the players can use a cost-free mechanism to agree to use it. Fourth, even if pricing costs are unimportant in many applications, they could still be critical in others.

To make the first two prongs of the argument, I present a brief literature survey to document the existence and importance of several pricing costs associated with bargaining and posted price mechanisms.

2.1. Bargaining Costs

Some version of alternating offer bargaining is commonly used to determine prices under conditions with a flavor of bilateral monopoly. Examples include big ticket consumer goods, industrial products, employment contracts, and other services. To make a list of the costs associated with this price determination process, I group them in three categories.

1. *Costs associated with the bargaining process itself*. Any explicit model of alternating offer bargaining must posit some costs of refusing an offer and making a counter offer, otherwise the process would go on ad infinitum. Delays are strictly out-of-equilibrium outcomes in the most simple models (Rubinstein 1982), but not in richer settings (Watson 1998).

Perhaps more important, bargaining often takes quite a bit of time in the real world. The costs of this time include the salary of bargainers, the loss from delays in trade, and the disutility many people feel from participating in the back-and-forth process (think of asking for a raise or buying a car). At a more aggregate level, the Bureau of Labor Statistics (May 2007, http://www.bls.gov/oes/current/oes_nat.htm) estimates that there are 65,600 Purchasing Managers in the United States each making an average of $81,440 per year. Because a survey by *Purchasing* Magazine suggests that these managers spend 15% of their time on price negotiations, we can estimate that the firms employing them incur close to one billion dollars in direct negotiation costs.

2. *Costs associated with the outcomes*. It has recently been argued that any not-ex-ante-agreed-upon outcome produces ill will towards the trading partner and a reduction in gains from trade (Hart and Moore 2008). More generally, players may experience lingering negative (and counterproductive) sentiments towards past bargaining opponents.

3. *Costs incurred in anticipation of bargaining*. It is well documented that better informed bargainers get better results (Busse et al. 2006). While this result does not figure prominently in the theoretical literature, it is not hard to understand. The idea is that players, prior to bargaining, can invest to get information that will help them in the bargaining process. Unless equilibrium investments equal collusive investments, there will be a distortion, i.e. a bargaining cost. In most cases it seems natural to assume that the cost comes in the form of both players overinvesting in jointly wasteful information.

Consistent with the importance of anticipatory bargaining costs, the above mentioned survey of purchasing managers also found that they spent about 25% of their time preparing bids and researching prices. At a more strategic level, players may refrain from suggesting improved trades to avoid bargaining, or withhold information about such opportunities to protect their own future bargaining power (Simester and Knez 2002).

2.2. Costs of Posting Prices

In situations where a single seller faces several buyers, it is common for the former to post a price that is understood to be a take-it-or-leave-it offer. Here are several costs of this process.

1. *Direct costs of posting a price*. Levy et al. (1997) estimate the direct costs of changing a supermarket price to be $.52. Depending on the setting, additional costs may be incurred to communicate the prices to buyers. In the case of a large industrial supplier, Zbaracki et al. (2004) find that the firm's total expense on pricing amounts to 1.22% of revenues.

2. *Seller costs of managing several different prices*. It is not unheard of for retailers to put all products in a small number of price classes to keep operations as simple as possible (5 and 10, Dollar Stores). In Zbaracki et al. (2004), the costs of managerial information gathering, decision-making, and communication were much larger than the conventional menu costs.

3. *Buyers' reactions to facing several different prices*. Several laboratory studies have suggested that buyers may purchase more when faced with fewer price classes (Chernev 2006). A recent field experiment by Bertini et al. (2006) yielded similar results and the authors attribute this to buyers' aversion to making complex trade-offs.

3. Characterization of Optimal Classes

As noted in §2, the costs of determining a price depend on the mechanism through which this is done e.g., by alternating offer bargaining or unilateral price posting. Because these costs contribute to the overall efficiencies of alternative price-determination mechanisms, attempts to economize on them should ideally take into account the endogeneity of the mechanism. However, to the extent that the nature of pricing costs varies between mechanisms, it would be very hard to perform a comparative analysis. Therefore, this paper focuses on the analysis of unilateral price posting.

In my reduced form model, the cost of pricing is represented only by the total cost r that must be incurred on a per price basis. By assuming that this cost is independent of the number of versions to which the price applies, I give the model economies of scale.

3.1. Preliminaries

The product comes in N possible versions, and if these are divided into $K \le N$ classes, the parties incur total pricing costs Kr. There is one seller (he) and B potential buyers (she), each of whom buys one or no units of the product. Versions are indexed by n or $q = 1, 2, \ldots, N$, classes by k or $j = 1, 2, \ldots, K$, and buyers by $b = 1, 2, \ldots, B$. The set of versions in class k is S^k and I use p_n to denote the price of version n, while p^k is the price for any version in class k. The notation $n \in k$ is shorthand for $n \in S_k$, such that $n \in k$ implies that $p_n = p^k$.

To keep the effects of costly pricing separate from those of screening, it is initially assumed that each buyer has very specific needs, such that only one version is right—has positive value—for any specific buyer (cf. Aghion and Tirole 1997). Because I can illustrate most of the intuition in the simple case in which versions have identical prior demands, but different costs, I start with that. The second subsection then focuses on the general case with differing costs and demands. Screening is introduced in the third subsection.

3.2. Identical Prior Demands, Different Costs

The seller can produce the n'th version of the product for $c_n \in [0, 1]$ and buyer b values this version at $v_{nb} \in [0, 1]$. The seller knows these costs at the outset and I label the versions such that $c_1 < c_2 < \cdots < c_N$. All BN values are ex ante unknown to the seller, and because pricing takes time and it is important to trade quickly, he has to set prices for all versions before hearing from the buyers. For buyer b, only one version, indicated by rb, is right. Ex ante, all versions are equally likely to be right for b, and thus have probability $1/N$ of being so. The value of rb, v_{rb}, is drawn from a commonly known distribution F: $[0, 1] \to [0, 1]$, independent of costs and i.i.d. across buyers and versions. The buyer values all other versions at 0. I indicate no trade by the version label 0, and define $v_{0b} = c_0 = p_0 = 0$. The addition of the no trade possibility means that the set of possible outcomes for a specific buyer can be described as an element of the set $\{0, 1, 2, \ldots, N\}$.

Except in §4, I assume that the seller designs the classes while the buyer selects the version to be traded. The sequence of events is

1. The seller learns his costs $(c_1, c_2, \ldots, c_N)$ and each buyer learns her valuations $(v_{b1}, v_{b2}, \ldots, v_{bN}) = (0, 0, \ldots, v_{rb}, \ldots, 0, 0)$.[1]
2. The seller groups the N versions into K classes and sets a price for each class.
3. Each buyer picks the version she wants to trade, if any.
4. Trades and payoffs.

Pricing costs are incurred even if no trades take place and because the seller sets the prices unilaterally, all pricing costs are charged to him. Analyzing the game backwards, buyer b selects version rb if $v_{rb} - p_{rb} > 0$ and otherwise makes no trade. To indicate the decisions made by buyers, I define $B(N+1)$ indicator variables such that $t_{bq} = 1$ if buyer b makes trade $q \in \{0, 1, 2 \ldots, N\}$ and $t_{bq} = 0$ otherwise. So

$$\begin{aligned} (t_{b0}, t_{brb}) &= (0, 1) \quad \text{if } v_{rb} - p_{rb} > 0, \\ (t_{b0}, t_{brb}) &= (1, 0) \quad \text{if } v_{rb} - p_{rb} \le 0, \quad \text{and} \\ t_{bq} &= 0 \quad \text{if } q \ne 0,\ rb. \end{aligned} \tag{1}$$

In Stage 2, the seller wants to find a number of classes K, a way to partition the N versions into these classes, $S = (S^1, S^2, \ldots, S^K)$, and a set of K prices to maximize the expected profits. With some abuse of notation, I use the Max_S operator as shorthand for the first two steps, such that the seller's problem can be written as

$$\begin{aligned} &\underset{S}{\text{Max}}\,\underset{p}{\text{Max}}\ E\sum_B\sum_K\sum_{q\in k}(p^k - c_q)t_{bq} - Kr, \\ &\quad \text{s.t. } (1), \quad U_k S^k = N, \\ &\quad \bigcap_{j\ne k} S^k S^j = \varnothing, \quad \text{and} \quad S^k \ne \varnothing \quad \text{for all } k. \end{aligned} \tag{2}$$

While Equation (2) in general is a very difficult problem, I have endowed it with sufficient structure to characterize the optimal solution in some detail.

First, because all buyers are ex ante identical, such that can solve Equation (2) at the level of a representative buyer, thus replacing the summation over B in favor of multiplication. Second, because all versions have identical prior valuations, the ex ante choice probabilities depend only on p. All versions in a class will therefore have equal choice probabilities and the seller's expected per-buyer profits are $\sum_K (p^k - c^k)[1 - F(p^k)]|S^k|/N - Kr/B$, where $|S^k|$ is the cardinality of S^k and c^k is the average cost of the versions in it. The optimal prices are then given by

$$p^{k*} = c^k + [1 - F(p^{k*})]/f(p^{k*}), \tag{3}$$

and the partitioning problem is

$$\begin{aligned} &\underset{S}{\text{Max}}\ \sum_K [1 - F(p^{k*})]^2 |S^k| / [Nf(p^{k*})] - Kr/B. \\ &\quad \text{s.t. } (3), \quad U_k S^k = N, \\ &\quad \bigcap_{j\ne k} S^k S^j = \varnothing, \quad \text{and} \quad S^k \ne \varnothing \quad \text{for all } k. \end{aligned} \tag{4}$$

While I am unable to solve this problem analytically, I can characterize its solution.

Proposition 1. *If prior demands are identical, it is never profit maximizing to have classes with interlacing costs.*

Proof. See appendix.

[1] It will often be more natural to assume that the buyer learns his valuation ex interim, between 2 and 3, but the present formulation will give the same results and preserves symmetry between the players.

This immediately gives

Corollary 1. *If prior demands are identical, the optimal classes can be defined by cost intervals, and class prices increase as average class costs go up.*

Recalling that versions are labeled in order of increasing costs, I label the classes such that the (average class) costs and profit maximizing prices p^{k*} are increasing in k. With these labels, if $c_q < c_n$, $n \in k$, and $q \in j$, then $j \le k$.

In terms of comparative statics, one sees immediately from Equation (4) that pricing costs (r) are more important when the number of buyers (B) is smaller and when the number of versions (N) is larger. So *the optimal number of classes is, ceteris paribus, smaller when the number of buyers is smaller and the number of versions is larger.* (Of course, the number of versions might be considered endogenous.) Intuitively, the seller can recoup more pricing costs if sales per version are larger. The employment relationship is a nice example of this effect. It would be absurd to set separate prices for the many tasks that never will be needed.

A much stronger characterization of the solution if F is uniform is offered next.

Finding 1. *If F is uniform, the profit maximizing partition for a given K is that which minimizes the sum of squared within-class deviations in costs.*[2]

Proof. See appendix.

This criterion appears in other fields as well. For example, both the k-means clustering algorithm (MacQueen 1967) from statistics and a widely used quantization technique from computer science (Gersho and Gray 1991) minimize the same criterion.[3] Here is an analytical proof that the procedure is optimal, although only in the knife-edge condition considered above.[4]

Remark 1A. It is tempting to conclude that the profit maximizing K is smaller when the variance in costs is smaller, but one can easily construct examples in which this conjecture is false. For example, if $c_1 = c_2 = 0.1$ and $c_3 = c_4 = 0.9$, K will be at most 2, while $c_1 = 0.1$, $c_2 = 0.4$, $c_3 = 0.6$, and $c_4 = 0.9$ may lead to a larger $K = 3$ or 4, in spite of having lower variance. However, it can be concluded that *the seller is more likely to set $K = 1$ when the variance in costs is lower*. Also this prediction can be understood with reference to the employment relationship (or Jellybeans). If the seller is roughly indifferent between trades, there is less need to incur significant price setting costs.

Remark 1B. As can be seen from Finding 1, the variance in values plays no role as long as all the values are drawn from the same distribution. Suppose, however, that some versions, if right, have values drawn from a uniform distribution on $[\rho, 1]$, where $\rho \in [0, 1]$, while others have values drawn from a uniform distribution on $[0, 1-\rho]$. In this case, the seller could reap larger benefits from putting the two types of versions in separate classes for larger values of ρ. So *in this example, the profit maximizing K will be weakly larger if the ex ante variance in values is larger in the sense that the distributions differ more between versions*. Intuitively, the seller will use fewer classes when demand differs less between versions because the prices would be similar even with zero pricing costs. (Formulation and demonstration of a more general result of this type is a topic for future research.)

The results obtained so far apply to the case in which all versions have identical prior demand, while ex post, each buyer assigns positive value to only one version. Continuing to maintain the latter feature (and thus ruling out screening), the case in which versions have different prior demands as well as different costs is considered next.

3.3. Different Prior Demands, Different Costs

Demand differences are incorporated by assuming that, if version n is right for b (such that $rb = n$), its value v_{rb} is drawn from a commonly known distribution F_n: $[0, 1] \to [0, 1]$ I.I.D. across buyers. It is also assumed that the vector of costs $c_1, c_2, \ldots, c_N$ and the family of distributions $F_1, F_2, \ldots, F_N$ satisfy a monotone scaled costs plus likelihood ratio property in the sense that there exists a labeling for which

$$\begin{aligned}&[c_n/p][F_n(P)-F_n(p)]/[1-F_n(P)]-[1-F_n(p)]/[1-F_n(P)]\\&\quad<[c_{n+1}/p][F_{n+1}(P)-F_{n+1}(p)]/[1-F_{n+1}(P)]\\&\qquad-[1-F_{n+1}(p)]/[1-F_{n+1}(P)] \qquad (MSC+LR)\end{aligned}$$

for all $p \in [0, 1]$, all $P \in [p, 1]$, and any $n \in \{1, 2, \ldots, N-1\}$. These labels will be referred to as indices of the corresponding versions. I adopt these labels.[5]

The sequence of events is the same as in §1. Again, the seller's problem is represented by Equation (2). Since the probability of $v_{rb} - p_{rb} > 0$ is

[2] For example, if $(c_1, c_2, \ldots, c_N) = (0.01, 0.02, \ldots, [0.01]N)$, where $N < 100$, and integer problems are ignored, Equation (10) can be written as $(N-K)r/B - (0.0001)(N-2K)(N-K)/(12K^2)$, and the optimal K is a root of $120{,}000rK^3 - BK^2 + 3NBK - 2BN^2 = 0$.

[3] The object of quantization is to compress a finer scale into a smaller set of discrete categories, while retaining as much relevant information as possible. The object of clustering is to organize a set of elements into groups that are in some way similar.

[4] As is well known, a uniform taste distribution gives linear demand and it is this linearity that provides the functional forms described in the finding. Thus, the error committed by using the criterion will vanish as demand approaches linearity.

[5] If costs are identical, we can use the likelihood ratio ordering to give us the labels.

$1 - F_{rb}(p^{rb})$, the seller's expected per-buyer profits are $\sum_K \{ \sum_{n\in k} (p^k - c_n)[1 - F_n(p^k)]/N\} - Kr/B$. The optimal prices are therefore given by

$$p^{k*} = \left\{\sum_{n\in k} c_n f_n(p^{k*}) + \sum_{n\in k}[1 - F_n(p^{k*})]\right\} \Big/ \sum_{n\in k} f_n(p^{k*}), \tag{5}$$

and the partitioning problem is

$$\begin{aligned}\operatorname*{Max}_S \ \sum_K \Bigg\{ &\left(\sum_{n\in k}[1 - F_n(p^{k*})]\right)^2 \Big/ \left[\sum_{n\in k} f_n(p^{k*}) N\right] \\ &+ \left(\sum_{n\in k} c_n f_n(p^{k*}) \sum_{n\in k}[1 - F_n(p^{k*})]\right) \Big/ \left[\sum_{n\in k} f_n(p^{k*}) N\right] \\ &- \sum_{n\in k} c_n [1 - F_n(p^{k*})] \Big/ N \Bigg\} - Kr/B. \end{aligned} \tag{6}$$

$$\text{s.t. } (5), \quad U_k S^k = N, \quad \bigcap_{j\neq k} S^k S^j = \varnothing, \quad \text{and} \quad S^k \neq \varnothing \quad \text{for all } k.$$

Proposition 2. *It is never profit maximizing to have classes with interlacing index values.*

Proof. See appendix.

Corollary 2. *The optimal classes can be defined by index intervals, and class prices increase as average class indices goes up.*

To see how the pricing cost rationale for class pricing interacts with the screening rationale, here is a simple example in which buyers treat products as substitutes.

3.4. Interaction Between Screening and Pricing Costs

To highlight the issues, this is a very simple example with three versions ($N = 3$) and three buyers ($B = 3$). I label the versions such that $c_1 < c_2 < c_3$ and assume that the valuations of buyer 1 are $(v_{11}, v_{12}, 0)$, while the valuations of buyers 2 and 3 are $(0, v_{22}, 0)$ and $(0, 0, v_{33})$, respectively, where $v_{22} < v_{11} = v_{12}$. In the absence of pricing costs, the seller would prefer to charge $(p_1, p_2, p_3) = (v_{11}, v_{22}, v_{33})$ and have buyer b (=1, 2, 3) buy version b. But because buyer 1 will prefer version 2 at these prices, the resulting profit is $2(v_{22} - c_2) + v_{33} - c_3$, and it is more profitable to charge $(p_1, p_2, p_3) = (v_{22}, v_{22}, v_{33})$ to get $2v_{22} - c_2 - c_1 + v_{33} - c_3$. *So the seller's inability to perfectly screen out buyer 1 has led to class pricing even if pricing costs are 0.*[6]

[6] Mussa and Rosen (1978) first demonstrated the possibility of this so-called bunching in the context of a screening model in which buyers differ in their taste for a single dimension. Later research has shown that bunching is extremely common in models with multidimensional screening (Renou 2003), essentially because the screener has too few instruments.

While screening distortions constitute a force towards class pricing, they are not incompatible with the effect proposed here. With the introduction of sufficiently high pricing costs in the previous example, the seller will prefer to save r by charging $\text{Min}\{v_{22}, v_{33}\}$ for all three versions.

In a general model with B buyers, N versions, and tastes $(v_{b1}, v_{b2}, \ldots, v_{bN})$, the indicator variables describing buyer behavior are now defined such that

$$\begin{aligned} t_{bq} &= 1 \ \text{ if } v_{pq} - p^q = \text{Max}\{v_{p1} - p^1, v_{p2} - p^2, \ldots, \\ &\qquad\qquad v_{pN} - p^N, 0\}, \quad \text{and} \\ t_{bq} &= 0 \ \text{ otherwise.} \end{aligned} \tag{7}$$

(Ties are ignored to keep the formalism down.) The sellers' problem is thus

$$\begin{aligned} &\operatorname*{Max}_S \operatorname*{Max}_p \ E \sum_B \sum_K \sum_{q\in k} (p^k - c_q) t_{bq} - Kr, \\ &\qquad \text{s.t. } (7), \quad U_k S^k = N, \\ &\qquad \bigcap_{j\neq k} S^k S^j = \varnothing, \quad \text{and} \quad S^k \neq \varnothing \quad \text{for all } k. \end{aligned} \tag{8}$$

In this problem, as in Equation (2), weakly fewer prices will be charged for higher pricing costs. Because of the complexity of Equation (7), it is, however, very difficult to characterize the solution without making strong assumptions on the distribution of the valuations.

Next is a detailed examination of a simple example in which the most efficient allocation of roles between buyer and seller is identified.

4. The Division of Roles Between Buyer and Seller

I have so far looked exclusively at the *Seller-Design-Buyer-Choice* game form, in which the seller designs the classes and sets the prices, after which the buyer chooses the version to be traded. Most examples use this game form, although there are exceptions, such as school district food contracts, in which the buyer insists on vegetables, but gives the seller discretion to select any one of several different seasonal vegetables.

It is not hard to understand why sellers, at least in business-to-consumer settings, almost invariably design the classes. If pricing is costly, it should be done by the thinner side of the market. So to investigate the optimality of the Seller-Design-Buyer-Choice game form I look at a case in which the two sides of the market are symmetric in the sense that there is a single buyer and a single seller. The most appealing candidate is the symmetric alternative in which the buyer designs the classes and sets the prices, after which the seller chooses the version to be traded.

There are, however, other possibilities as well. The two alternatives in which the same player designs and chooses are most easily thought of in a sequential sense in which (1) one player first designs the classes, (2) the opponent then sets prices, and (3) the first player finally chooses. In both of these cases, the design of the classes reflect private information (costs or values) that is not available to the player setting prices. Because the resulting jockeying for information rents will burden both game forms with additional inefficiencies, and I ignore them in the following. The last two logical possibilities, in which the same player sets prices and chooses, are clearly very inefficient unless the opponent is given the right to refuse. Because this introduces factors not present in the simpler game forms, I also ignore this last pair of alternatives.

To keep the analysis simple, I look at a case with two versions and assume that costs are binomial and i.i.d. across versions. In particular, values are $\gamma \in [0, 1/2]$ or $1-\gamma$, each with probability 1/2, and costs are 1/3 or 2/3, also each with probability 1/2. Noting that the buyer's valuations are more (less) varied than the seller's when $\gamma < 1/3$ ($\gamma > 1/3$), I evaluate the relative efficiency of alternative game forms for varying values of γ relative to 1/3. The cost of determining a price is $r \geq 0$.

Recall that the sequence of events in Seller-Design-Buyer-Choice is as follows

1. The seller learns his costs and the buyer learns her valuations.
2. The seller groups the 2 versions into 1 or 2 classes and sets prices.
3. The buyer picks the version she wants to trade, if any.
4. Trades and payoffs.

I compare the ex ante efficiency of this to the logical alternative, *Buyer-Design-Seller-Choice*, in which

1. The seller learns his costs and the buyer learns her valuations.
2. The buyer groups the 2 versions into 1 or 2 classes and sets prices.
3. The seller picks the version she wants to trade, if any.
4. Trades and payoffs.

By proceeding mechanically and working through a lot of algebra, I can derive an appealing result about the relative efficiency of the two game forms. In particular, I can show

Finding 3. *For any $r \geq 0$, the Buyer-Design-Seller-Choice is the more efficient game form when $\gamma < 1/3$, while Seller-Design-Buyer-Choice is more efficient when $\gamma > 1/3$.*

Proof. See appendix.

Since the seller's (the buyer's) valuation is relatively less variable exactly when $\gamma > 1/3$ ($\gamma > 1/3$), this implies:

Corollary 3. *Classes in bilateral trades should be designed by the player with the less variable valuations, while the version traded should be chosen by the player with the more variable valuations.*

Although classes in most examples are designed by the seller, the above result helps make sense of this, and the exceptions. In particular, many incomplete contracts give the seller latitude in determining the attributes about which the buyer cares little. One such example is home renovation contracts, which leave the contractor with the flexibility to make many minor decisions in light of local conditions. However, in most cases it is the buyer who cares more about which version is traded, and is thus given the right to choose.

While this result has strong intuitive appeal and considerable face validity, it clearly depends on trade being bilateral.

5. Discussion

This paper has introduced the concept of class pricing as a response to the costs of assigning prices to large numbers of products. Class pricing is more likely to be used when the number of buyers is smaller, the number of versions is larger, variance in costs are smaller, and demand ex ante differs less between versions. Sellers will define classes by cost intervals, and in a simple but natural case, the profit maximizing class design is that which minimizes the sum of squared within-class cost deviations. In bilateral trades, the most efficient game form is that in which classes are designed by the player with fewer varied gains from trade, while the traded version is chosen by the other player.

Once you start looking for it, class pricing is, as suggested by the examples in the opening paragraph of the paper, a very widely observed phenomenon. In many cases, (Jellybeans, haircuts, fast food, …) it can be argued that the aggregate implications of exactly identical prices are very similar to those of slightly differing prices. In other cases, (university educations, all-inclusive resorts, …) one could question the practice and probe its justification. Finally, there are some cases in which the implications are much less trivial.

It is possible to think of class pricing as an endogenously incomplete contract. A very large set of versions can be defined by considering all levels of all attributes left out of the contract. Each of these attributes is often (de facto) left for a specific player to decide. For example, in a home-renovation contract, it is understood that the buyer can select colors, while the seller decides on almost all hidden aspects of construction. According to the analysis presented here, these are attributes about which the deciding player cares the most. By contrast, the opponent is so indifferent that it simply is not worth it to negotiate different prices for all versions.[7]

Next I briefly discuss some important questions left for future research. First, because the models and examples analyzed here are quite special, it will be important to develop a more general version of the theory. The computational difficulties associated with the partitioning problem will likely prove a significant hurdle. However, if the computer science literature is a good analogy, one can hope to show that the solution from Finding 1: *Minimize the sum of squared within-class cost variations*, is approximately optimal in a larger class of problems. If so, it would be much easier to do further work in the area. Second, while we have assumed a single seller throughout, it would be interesting to look at competitive class design. Suppose there are many sellers with privately known costs drawn from the same commonly known distribution. In this case, prices should go down, thus depressing the advantages of having more classes. If the per-seller costs of pricing stay the same, one would therefore expect fewer classes with more competition. Alternatively, a small number of sellers may be able to play an equilibrium in which they use different classes, allowing each to cater to its own market segment, much like in a model with spatial differentiation. Third, while we have focused on classes defined by identical unit prices, one could imagine a more general theory of classes defined by identical contracts. Employees work on hourly pay and most multiproduct sales forces receive the same commission rate regardless of the product sold. This line may eventually lead to a theory of contractual simplicity. Finally, and perhaps most important, it would be interesting to test some of the predictions made in the paper, perhaps by exploiting different pricing practices between countries or across different periods in history.

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Appendix. Proofs

Proof of Proposition 1. If versions n and $n+2$ are in class k, then version $n+1$ should be in class k as well. To see this, note that if version $n+1$ is in a higher priced class, it is traded with lower probability than version $n+2$, implying that the seller could do better by switching the two versions. Similarly, if version $n+1$ is in a lower priced class, it is traded with higher probability than version n. Q.E.D.

Proof of Finding 1. By substituting in the optimal class prices, $p^{k*} = 1/2 + c^k/2$, the ex ante expected per-buyer profits are

$$\left[1+\sum_K (c^k)^2|S^k|/N - 2\sum_N c_n/N\right]\Big/4 - Kr/B. \tag{9}$$

If $K = N$, (9) becomes $[1 + \sum_N (c_n)^2/N - 2\sum_N c_n/N]/4 - Nr/B$, and I can express the net advantage of class pricing as

$$(N-K)r/B - \left[\sum_N (c_n)^2 - \sum_K |S^k|(c^k)^2\right]\Big/N. \tag{10}$$

The first term in Equation (10) reflects the saved pricing costs and the second the loss from less than optimal pricing of individual versions. The finding follows from rewriting Equation (10) as

$$(N-K)r/B - \left[\sum_K \sum_{n\in k} (c_n - c^k)^2\right]\Big/N. \quad \text{Q.E.D.} \tag{11}$$

Proof of Proposition 2. Suppose that version $n+1$ is priced below version n, such that $p_{n+1} = p$ and $p_n = P$, where $p < P$. The seller's expected profit from these two versions is then $[P - c_n][1 - F_n(P)] + [p - c_{n+1}][1 - F_{n+1}(p)]$. This is higher than the profit from charging p for both versions if

$$[P - c_n][1 - F_n(P)] > [p - c_n][1 - F_n(p)], \tag{12}$$

and higher than the profits from charging P for both versions if

$$[p - c_{n+1}][1 - F_{n+1}(p)] > [P - c_{n+1}][1 - F_{n+1}(P)]. \tag{13}$$

Taken together Equations (12) and (13) require that

$$\begin{aligned}&\{1-F_n(p)-[F_n(P)-F_n(p)]c_n/p\}/\{1-F_n(P)\} < P/p\\ &< \{1-F_{n+1}(p)-[F_{n+1}(P)-F_{n+1}(p)]c_{n+1}/p\}/\{1-F_{n+1}(P)\}\end{aligned} \tag{14}$$

But this contradicts $(MSC + LR)$. Q.E.D.

Proof of Finding 3. In the following, $E\pi$ denotes the seller's expected profits, EU is the buyer's expected utility, and EL is the amount by which the sum of these falls short of the first best. Proceeding mechanically, I compare the performance of the two game forms for $\gamma < 1/3$ and $\gamma > 1/3$.

Case 1. $\gamma < 1/3$, *Seller-Design-Buyer-Choice.*

For $K = 2$, the profit maximizing prices, associated efficiency losses, and profits prior to pricing costs, are:

$(p_1, p_2 \mid c_1 = c_2 = 1/3) = (1-\gamma, 1-\gamma)$, $EL = 0$, $E\pi = 1/2 - 3\gamma/4$,

$(p_1, p_2 \mid c_1 = 1/3, c_2 = 2/3) = (1-\gamma-\varepsilon, 1-\gamma)$, $EL = 0$, $E\pi = 5/12 - 3\gamma/4$,

$(p_1, p_2 \mid c_1 = c_2 = 2/3) = (1-\gamma, 1-\gamma)$, $EL = 0$, $E\pi = 1/4 - 3\gamma/4$.

For $K = 1$, the profit maximizing price, associated efficiency losses, and profits prior to pricing costs, are

$p^1 = 1-\gamma$, $EL = 0$, $E\pi$ are as if $K = 2$, except that $E\pi = 3/8 - 3\gamma/4$ if $c_1 \neq c_2$.

So the seller will ex ante prefer $K = 2$ if $r < 1/48$. However, the game form implements the first best for either value of K and thus for all values of $r \geq 0$.

[7] Price negotiation may result if the opponent is not indifferent, but this is relatively rare.

Case 2. $\gamma < 1/3$ *Buyer-Design-Seller-Choice.*

For $K = 2$, the utility maximizing prices, associated efficiency losses, and utilities prior to pricing costs, are

$(p_1, p_2 \mid v_1 = v_2 = \gamma) = (0, 0)$, $EL = 0$, $EU = 0$,

$(p_1, p_2 \mid v_1 = \gamma, v_2 = 1 - \gamma) = (0, 1/3)$, $EL = 1/6 - \gamma/2$, $EU = 1/3 - \gamma/2$,

$(p_1, p_2 \mid v_1 = v_2 = 1 - \gamma) = (1/3, 1/3)$, $EL = 1/12 - \gamma/4$, $EU = 1/2 - 3\gamma/4$,

If $K = 1$, the utility maximizing price, associated efficiency losses, and utilities prior to pricing costs, are

$(p^1 \mid v_1 = v_2 = \gamma) = 0$, $EL = 0$, $EU = 0$.

$(p^1 \mid v_1 = \gamma,\ v_2 = 1 - \gamma) = 1/3$, $EL = 1/8 - 3\gamma/8$, $EU = 1/8$.

$(p^1 \mid v_1 = v_2 = 1 - \gamma) = 1/3$, $EL = 1/12 - \gamma/4$, $EU = 1/2 - 3\gamma/4$.

So the seller will ex ante prefer $K = 2$ if $r < (5 - 12\gamma)/48$. However, the game form implements the first best for neither value of K and thus for no values of $r \geq 0$.

Case 3. $\gamma > 1/3$, *Seller-Design-Buyer-Choice.*

For $K = 2$, the profit maximizing prices, associated efficiency losses, and profits prior to pricing costs, are

$(p_1, p_2 \mid c_1 = c_2 = 1/3) = (1 - \gamma, 1 - \gamma)$, $EL = \gamma/4 - 1/12$, $E\pi = 1/2 - 3\gamma/4$

$$
\begin{aligned}
(p_1, p_2 \mid c_1 = 1/3, c_2 = 2/3)
&= (1 - \gamma, 1) \quad \text{if } \gamma \in (1/3, 4/9],\ EL = \gamma/2 - 1/6,\\
&\qquad E\pi = 1/3 - \gamma/2\\
&= (\gamma, 1) \quad \text{if } \gamma \in (4/9, 1/2],\ EL = 0,\ E\pi = \gamma - 1/3
\end{aligned}
$$

$(p_1, p_2 \mid c_1 = c_2 = 2/3) = (1, 1)$, $EL = 0$, $E\pi = 0$.

If $K = 1$, the profit maximizing price, associated efficiency losses, and profits prior to pricing costs, are

$$
\begin{aligned}
(p^1 \mid c_1 = c_2 = 1/3)
&= 1 - \gamma \quad \text{if } \gamma \in (1/3, 10/21],\ EL = \gamma/4 - 1/12,\\
&\qquad E\pi = 1/2 - 3\gamma/4\\
&= \gamma \quad \text{if } \gamma \in (10/21, 1/2],\ EL = 0,\ E\pi = \gamma - 1/3
\end{aligned}
$$

$(p^1 \mid c_1 = 1/3, c_2 = 2/3) = 1 - \gamma$, $EL = 1/24 - \gamma/8$, $E\pi = 1/2 - \gamma$

$(p^1 \mid c_1 = c_2 = 2/3) = 1$, $EL = 0$, $E\pi = 0$

So the seller will ex ante prefer $K = 2$ if $r < (3\gamma - 1)/12$ and $\gamma \in (1/3, 4/9]$, $r < \gamma - 1/3$ and $\gamma \in (4/9, 10/21]$, and if $r < (27\gamma - 10)/48$ and $\gamma \in (10/21, 1/2]$. However, the game form implements the first best for neither value of K and thus for no values of $r \geq 0$.

Case 4. $\gamma > 1/3$, *Buyer-Design-Seller-Choice*

For $K = 2$, the utility maximizing prices, associated efficiency losses, and utilities prior to pricing costs, are

$(p_1, p_2 \mid v_1 = v_2 = \gamma) = (1/3, 1/3)$, $EL = 0$, $EU = 3\gamma/4 - 1/4$

$(p_1, p_2 \mid v_1 = \gamma, v_2 = 1 - \gamma) = (1/3, 1/3 + \varepsilon)$, $EL = 0$, $EU = 1/4 - \gamma/4$

$(p_1, p_2 \mid v_1 = v_2 = 1 - \gamma) = (1/3, 1/3)$, $EL = 0$, $EU = 1/2 - 3\gamma/4$.

If $K = 1$, the utility maximizing price, associated efficiency losses, and utilities prior to pricing costs, are

$(p^1 \mid v_1 = v_2 = \gamma) = 1/3$, $EL = 0$, $EU = 3\gamma/4 - 1/4$

$(p^1 \mid v_1 = \gamma, v_2 = 1 - \gamma) = 1/3$, $EL = 0$, $EU = 1/8$

$(p^1 \mid v_1 = v_2 = 1 - \gamma) = 1/3$, $EL = 0$, $EU = 1/2 - 3\gamma/4$

So the buyer will ex ante prefer $K = 2$ if $r < (1 - 2\gamma)/8$. However, the game form implements the first best for either value of K and thus for all values of $r \geq 0$.

The desired result then follows by combining the results from the four cases. Q.E.D.

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