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Multiproduct Pricing in Major League Baseball: A Principal Components Analysis

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Multiproduct Pricing in Major League Baseball: A Principal Components Analysis [1]

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Abstract

The empirical analysis of multiproduct pricing suffers from a lack of clear theoretical guidance and appropriate data, limitations which often render traditional regression-based analyses impractical. This paper analyzes ticket, parking, and concession pricing in Major League Baseball for the period 1991-2003 using a new methodology based on principal components, which allows inferences to be formed about the factors underlying price variation without strong theoretical guidance or abundant information about costs and demand. While general demand shifts are the most important factor, they explain only half of overall price variation. Also important are price interactions that derive from demand interrelationships between goods and the desire to maximize the capture of consumer surplus in the presence of heterogenous demand.

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1. Introduction

Analyzing the pricing decisions of a multiproduct firm presents a daunting challenge for the researcher. While this problem has received considerable theoretical attention, empirical analyses are scarce despite the ubiquity of the problem in practical business decisions.

This is for good reason. Several methodological issues complicate the empirical analysis of multiproduct pricing: a large number of relevant variables, both dependent and independent; scant data on some of these variables; estimation difficulties; and complex theoretical relationships that cannot be simplified without strong assumptions. These formidable obstacles have sharply limited the number of empirical analyses of multiproduct pricing and compromised the ease and rigor with which they are conducted. As a result, the literature contains neither a set of stylized facts about multiproduct firms' pricing behavior nor a facile methodology with which to obtain those facts.

These issues all arise in the subject of our inquiry, pricing in Major League Baseball (MLB), a topic of longstanding interest in sports economics and the quintessential multiproduct pricing problem. Operating in geographically isolated markets, most baseball teams are local monopolists; all sell multiple products including tickets, parking, and concessions, at prices that vary substantially and non-uniformly across teams and across time. All primary factors emphasized in the theory of multiproduct pricing are potentially relevant: the general demand for any team's "product bundle" fluctuates substantially over time, while the products sold by the team are related in demand and potentially subject to nonlinear pricing, such as second-degree price discrimination, in order to maximize the capture of consumer surplus.

Yet a structural analysis of multiproduct pricing in Major League Baseball is impractical because of all of the issues identified above. The required concession quantity or revenue data are simply not available; nor are good instruments for prices. Beyond the heuristics listed above, the theory of multiproduct pricing is not well developed for this straightforward yet non-trivial case, which combines an obligatory entry fee (the ticket price) with complementary, discretionary, multiple-purchase concessions. Furthermore, a structural model, which explains prices in terms of many costs and demand elasticities, would not easily or naturally illuminate these heuristics. Progress requires a methodology that needs little a priori theoretical structure while accommodating many prices but limited data on quantities, costs, and demand. Traditional econometric techniques clearly do not satisfy these requirements, but there are complementary alternatives that do.

One such option is a factor analytic technique, principal components analysis. This reveals, rather than imposes, structure in the data, breaking price co-movements down into a few independent patterns that can be interpreted heuristically and tested rigorously and simply. With a long history of successful use in a variety of social and natural science applications, including several in economics and finance, the technique has an established track record. And it is well suited to the analysis of multiproduct pricing, whose fundamental concepts are easily articulated heuristically.

In this paper we utilize principal components to analyze the pricing decisions of MLB teams from 1991-2003. Our principal objectives are to identify the primary factors underlying pricing and to relate them to economic theory. Our secondary objective is to illustrate how principal components can usefully facilitate the analysis of multiproduct pricing. We find that the factors stressed by theory are indeed relevant in MLB. A general demand effect explains about half of the joint variation in prices charged by teams, while changes in price differentials across products associated with second-degree price discrimination and demand complementarities explain another twenty percent, with price discrimination seemingly the more important of the two.

Recognizing the novelty of using principal components in this context, we begin by describing how to this method to analyze multiproduct pricing, and compare it to structural modeling. Section 3 discusses the theory and evidence on the pricing decisions of MLB teams and describes the data, while Section 4 presents the empirical results. The final section provides conclusions.

2. Multiproduct Pricing: Theory and Practice

A. Structural Models

A structural model expresses prices in terms of demand parameters and costs, specifying the functional form using economic theory. These models can be used to test theory, to infer the type of competition present in the market, or for policy analysis. For example, Guilietti and Waterson (1997) use structural estimation to determine whether competitive retailers price their products as predicted by Bliss (1988), while DubJ (2005) uses it to infer the effects of mergers in the soft drink industry on prices and welfare.

Each price markup in a structural model depends, in general, on the firm-level own- and cross-elasticities of demand for all products in the market. This focus on behavioral fundamentals makes these models well suited to policy analysis, but also demands a lot of data, because the number of parameters is sizeable even when there are just a few products and increases rapidly when there are more products. Estimation thus requires extensive price and quantity data and a mechanism to account for price endogeneity. Guilietti and Waterson, for example, were forced to aggregate 31 products into seven categories to permit estimation, and utilized industry, rather than firm, elasticities because of data limitations. The problem is magnified when analyzing price dynamics (DubJ et al., 2005), which has not yet been done using the structural approach.

Structural estimation also requires a lot from theory. The theoretical structure imposed on the analysis increases and strengthens the inferences one can draw from the data as long as the appropriate functional relation can be specified in advance. But this is often hard to do for multiproduct pricing, where these relations are generally complex, sensitive to model assumptions (Spence, 1980), "rather opaque as to intuitive content" (Sibley and Srinagesh, 1997), and "difficult to apply empirically" (Bliss, 1988).[2] Even when properly specified, estimation is not simple. DubJ, for example, relies on numerical techniques (Monte Carlo integration and the method of simulated moments) to obtain parameter estimates of his model.

Thus the power of structural modeling comes at a cost, which limits both the type and number of empirical studies that can be executed. This motivates the introduction of an alternative method that can uncover relationships and answer questions structural modeling cannot, while requiring less data, theoretical structure, and computational effort.

B. Principal Components

The factor-analytic perspective treats prices as governed by a few uncorrelated, unobserved, underlying latent variables. Principal components analysis can recover these latent variables and their relation to prices. A common technique for "untangling complex patterns of association in multivariate data" (Green, 1978), principal components has been used to analyze the market prices of

[2] Mirrlees (1976) set out the complete solution for nonlinear monopoly multiproduct pricing, a complex function of elasticities, costs, and endogenous Lagrange multipliers. Simple relations appear only under restrictive conditions that exclude many realistic pricing situations such as that analyzed here. Cost-based two-part tariffs are nearly optimal when goods are neither substitutes nor complements and the number of goods is large (Armstrong, 1999). Two-part tariffs also obtain when duopolists compete sufficiently and certain other conditions apply (Armstrong and Vickers, 2001; Rochet and Stole, 2002). Optimal nonlinear prices can be determined separately for each market when preferences satisfy a strong condition called the "uniform ordering of demand curves" (Sibley and Srinagesh, 1997). Competitive retailing margins are a constant percentage across all goods when consumers are "fixed budget shoppers" (Bliss, 1988).

shrimp (Doll and Chin, 1970), asset prices (Roll and Ross, 1980, and others), business cycles (Forni and Reichlin, 1998), industry profitability (Slade, 2004), and government regulation in the U.S. economy (Goff, 1986). Here, the patterns obtained provide a heuristic description of the primary determinants of prices that can be linked to theory via empirical tests that can be feasibly conducted in a wide range of applications.

One observes a sequence of prices set by a multiproduct firm on each of N goods. The analysis decomposes each price vector, P_j, into a linear function of N independent latent variables, or principal components, Z_k, weighted by scalar coefficients A_k: $P_{j,t} = \mathbf{E} A_{k,j} Z_{t,k}$, k=1..N. These terms are determined by the way the principal components are calculated; none are pre-specified. Thus analytical structure is imposed on the data, as in any parametric analysis, but little theoretical structure is imposed.

Each latent variable Z_k is determined, up to an arbitrary scale factor, by demeaning the price matrix P and calculating the eigenvectors and eigenvalues of $P^T P$, placing the former in a diagonal matrix λ and the associated orthonormal eigenvectors in matrix A (Green, 1978; Johnson and Wichern, 1982).[3] These matrices satisfy $A^T P^T P A = \lambda$. The matrix of principal components Z is set equal to the matrix product PA; its covariance matrix is then λ. Prices are then reconstructed by $P = ZA^T$, as above. While the number of components equals the number of prices, typically most variation is explained by a few components with meaningful interpretations; the others are essentially noise, or "scree." The sum of the eigenvalues equals the sum of the variances of all prices, so the fraction of joint price variation attributable to component k equals $\lambda_{kk}/\mathrm{tr}(\lambda)$.

The eigenvalues and associated eigenvectors are conventionally put in descending order. Then the first eigenvector contains weights, or factor loadings, that yield the linear combination of the prices in P with the largest variance, restricting the sum of the squared weights to equal one. The second eigenvector yields that linear combination (independent of the first eigenvector) with the largest "remaining" variance, and so on. If the main factors underlying price variation are those suggested by economic theory, the first few eigenvectors should be interpretable as such, while the remaining eigenvectors should be uninterpretable and should explain little of the variation in P. Interpretations of the eigenvectors can be framed as hypotheses about the associated principal component and tested in

[3] Customarily each variable is normalized by its standard deviation, as principal components analysis can be sensitive to the scale of the variables. Here this highlights the interplay of prices, the focus of the analysis.

the usual way using observed independent variables X. The interpretation of component k may imply coefficient signs on the vector **(** in the regression Z_k = **(**X + **<**.

Thus principal components analysis is wholly complementary to structural estimation. The inferences yielded are general, not detailed: price changes are explained heuristically in terms of the latent variables. The data requirements are modest and computation is trivial. These features are particularly valuable given that the basic mechanics of multiproduct pricing have not been comprehensively documented because of computational complexities and data limitations.

C. Comparison and Illustration

We illustrate these points with a two-good, stylized quasi-structural model that closely echoes our analysis of MLB pricing. A monopolist sets these goods' prices based on general demand, measured by a cardinal index G, and the variable cost of producing the second good, C. The goods are complements, so increases in C raise the price of good 2, P_2, and lower the price of good 1, P_1 (Forbes, 1988):

$$P_1 = \alpha_1 + \beta_1 G - \gamma_1 C$$
$$P_2 = \alpha_2 + \beta_2 G + \gamma_2 C$$

where all parameters are positive. These can be estimated directly if G and C are measured; then the monopolist's behavior is fully explained. In many instances, however, including our own, only imperfect proxies are available. Then one cannot break down prices, or price variation, into components associated with demand or costs using structural methods.

But appropriately weighted linear combinations of these prices reflect demand and costs perfectly:

$$P_1 + wP_2 = \alpha + \beta G$$
$$P_1 + w^*P_2 = \alpha^* + \gamma^* C$$

If these weights ($w = \gamma_1/\gamma_2$, $w^* = -\beta_1/\beta_2$) could be ascertained, perfect correlates of G and C can be created and then used to reconstruct prices: the monopolist's behavior is, again, fully explained.

Principal components analysis approximates these weights when the effects of G and C on prices are roughly independent, as illustrated in Figure 1. The ellipse delineates, or circumscribes, the bivariate distribution of realized prices. The effect of general demand shifts on prices is illustrated by line GG, with slope β_2/β_1, and that of cost changes is illustrated by line cc, with slope $-\gamma_2/\gamma_1$. Principal components will extract the exact weights w, w* if $\beta_2\gamma_2/\beta_1\gamma_1 = 1$, and will approximate them otherwise, as the major axis, MM, containing the price combination with the greatest variance differs somewhat from line GG, and similarly for the minor axis, mm.[4]

But one need not merely speculate whether the approximation is good. It can be checked by "auxiliary regressions" relating each component to observed demand and cost proxies œ and †:

$$P_1 + \text{ë}P_2 = \alpha_1 + \beta\text{œ} + \gamma\text{†} + \varepsilon$$
$$P_1 + \text{ë}^*P_2 = \alpha^* + \beta^*\text{œ} + \gamma^*\text{†} + \varepsilon^*$$

where ë, ë* are the weights yielded by the principal components analysis and ε, ε^* are error terms. If these components accurately reflect the contributions of demand and costs, four testable hypotheses should be satisfied: $\beta > 0$, $\gamma = 0$, $\beta^* = 0$, and $\gamma^* < 0$. If they are satisfied, theoretical content has been successfully extracted from the interactions between prices.

The technique is even more valuable when one is analyzing multiple prices instead of just two, so that P_1 and P_2 represent vectors, not scalars. One set of goods is complementary to the other set, so the same model applies to the prices appropriately grouped. Principal components analysis then yields vectors of weights ë and ë* that approximate these groupings (which need not be specified in advance). That is, if general demand is the strongest influence on prices, the first eigenvector should have positive weights on all prices, and the next, reflecting the influence of costs, should have negative weights on the prices in vector P_1 and positive weights on those in P_2. The remaining components represent noise. As before, the validity of these groupings can be tested using the above regression. Principal component analysis is a data reduction tool as well.

It is also particularly valuable in the presence of pricing influences other than costs or demand, "institutional factors" such price restrictions or the ability to price discriminate. Compared to other structural economic models generally, structural monopoly pricing models are *austere*: a single decision maker utilizes a tightly defined set of relevant variables—demand parameters and costs. Yet

[4] Though of no consequence for this example, principal components technically weights not one price but both, so that the sum of the squared weights equals one. Thus, the first component could be expressed as $\sin(\theta)P_1 + \cos(\theta)P_2$, where $\theta = \arctan(\beta_2/\beta_1)$ if the "exact weights" are extracted.

even here institutional factors can sometimes play a role. These may not be easily quantified or formally modeled, and so can be hard to analyze or identify using structural methods. Principal components can handle these factors more easily because they often can be treated, or thought of, as latent variables. This property turns out to be important for our analysis, as both institutional factors listed above influence pricing in MLB.

D. Implementation

The major concern in using principal components analysis is the potential for unjustified interpretations of the results. We address this concern by analyzing a situation that is particularly conducive to use of the technique and by shaping the methodology accordingly.

Foremost, the austerity of the monopoly pricing problem supports the use of principal components. Much economic data represent an aggregate of multi-party, decentralized decision-making. Many factors may generate correlations between the dependent variables, complicating and weakening the interpretation of the factor loadings. This is not so here: the monopolist controls all pricing decisions, directly or indirectly (through contracts with concessionaires), and there are strong priors about the key variables that drive these decisions (demand parameters and costs) and how they influence price (at least heuristically). Clearly identifiable, plausible pricing patterns in accord with these priors and supported by auxiliary regressions like those depicted above can reasonably be interpreted as such.

Furthermore, our implementation of the technique is structured to safeguard against excessive interpretation. We begin with a theoretical analysis that determines whether the market is an appropriate application: whether prices are plausibly determined by a few underlying, independent factors. Heuristics are produced in the next step, the principal component analysis itself, by interpreting the factor loadings. These are not considered definitive, but rather hypotheses to be checked. Initially this is done informally, in the third step, by conducting principal component analyses on the same prices in other markets. Our hypotheses are suspect if the factor loadings are similar in markets in which the factors underlying pricing are believed to be different, or vice versa. Finally, formal hypothesis tests are conducted by regressing Z on X, as outlined above.

3. Major League Baseball: An Industry Case Study of Multiproduct Pricing

A. *Studies of Pricing in Major League Baseball*

Major League Baseball presents a classic case of multiproduct pricing. The game "package" purchased by most MLB fans includes a combination of tickets, parking, food concessions, and other concessions such as programs. These products are relatively homogenous across firms within the industry, and most ball clubs are isolated local monopolies. (The eight teams that play in the same metropolitan area, such as the New York Yankees and the New York Mets, have distinctly different fan bases—see Depken, 2000—and significant monopoly power.)

For years the trade publication *TMR* has reported the posted prices of tickets, parking, and several concessions for the four major professional sports leagues in the United States, and from these calculated a Fan Cost Index (FCI) reflecting the expenses incurred by a hypothetical family of four that attends a game, parks at the stadium, and consumes a typical mix of concessions. For 2004, the MLB average FCI was $155.52, of which ticket costs, at $78.98, were barely half. Thus expenditures on parking and concessions are likely to be quantitatively important.

Nonetheless, a comprehensive analysis of the relationship between the various prices in MLB (or any other sporting league) has yet to be undertaken—again, because data limitations do not allow it to be done using traditional methods. Instead, previous studies focus on the relation between ticket prices and attendance (Depken, 2001; Marburger, 1997; Scully, 1989; and Zimbalist, 1992) or whether ticket prices are set optimally given the near-zero cost of seating additional fans (Ferguson, et al., 1991; Scully, 1989, pp. 111-113; and Zimbalist, 1992, p. 214).

For single-good pricing, this would be where demand is unit elastic and revenue is maximized. Most studies find, instead, prices are set where ticket demand is inelastic (Krautmann and Berri, 2007). This vexing outcome may be explained by accounting for other costs of attendance, which are omitted from most of these studies, and their relation to ticket prices.[5] The effect of ticket price changes on attendance will be muted if concession prices move in the opposite direction, as theory suggests can happen and our results suggest does happen, biasing downward price elasticities estimated using ticket prices alone. Furthermore, pricing where ticket demand is inelastic may be optimal under these circumstances, as revenue lost from ticket price reductions can be recaptured through increased

[5] Notable exceptions are Welki and Zlatoper (1994), who include the cost of parking in a study of NFL demand, Depken (2000) who includes average concession expenditures in a study of baseball demand, and Winfree et al. (2004), who proxy for the total cost of attending a game using a travel time measure. None of these measures, however, completely reflect the full costs of attending a sporting event.

concession demand, again as suggested by theory (Marburger, 1997; Krautmann and Berri, 2007) and our empirical results. Thus our analysis can advance these strands of the sports economics literature while also contributing to industrial organization.

B. Multiproduct Pricing in Major League Baseball

While the above-mentioned features of MLB make it suitable for analysis from an empirical perspective, other features of the market make it suitable from a theoretical perspective. In particular, economic theory has identified three general reasons that the prices of goods sold by a multiproduct monopolist would be related, and each is well represented in MLB.

The first possible source of price correlations is a change in general demand for the game "package," stemming perhaps from a surge in team popularity or greater income in the team's market area. An increase in general demand should exert upward price pressure for all goods in the game package, because each good is quite distinct and has a positive income elasticity. Similarly, a decrease in demand should exert downward price pressure on all goods. Thus the "pricing signature" of general demand shifts is positive co-movement of all prices, as before. This signature is unique, and will not be generated by a general increase in costs, as shown below.

Demand interrelations between goods also affect price setting. Here, the most important relation is between tickets and concessions, which enhance the game-viewing experience. Tickets and concessions can therefore be considered two composite, complementary goods. For the two-good case, Forbes (1988) shows how the prices of complements respond to changes in cost or demand. Increases in both products' demands or both products' production costs should increase both products' prices. But an increase in the cost of or demand for just one of the products will increase its price and decrease the price of its complement.

Because the marginal cost of tickets—additional game attendance—is virtually zero, increases in factor prices should affect the cost of concessions only. Thus cost increases will raise concession prices and, through Forbes' logic, *decrease* ticket prices. Similarly, idiosyncratic demand shifts for one of these composite goods will increase its price and lower the price of the other good. The pricing signature of cost or idiosyncratic demand shifts is a negative relation between ticket prices and concession prices. This signature is clearly distinct from that of general demand shifts.

Finally, product prices can be related because of nonlinear pricing that attempts to maximize the capture of consumer surplus in the face of heterogenous consumer demand (product demand that differs across consumer types). Common forms of nonlinear pricing include second-degree price discrimination, in which consumers can pay a fixed "entry fee" in order to purchase some range of quantities at a price below "list," and the selling of bundled products at a discount. In MLB, nonlinear pricing can generate price interactions across tickets and concessions because some of the surplus generated by lowering concession prices can be extracted in ticket prices, as exactly one ticket is required of each patron. The degree to which this is done depends on the extent of consumer heterogeneity and teams' ability to extract surplus through ticket prices. While all stadiums offer a range of seating options and ticket prices, some have a greater range than others. Those teams are probably the most able to extract consumer surplus in this way, and should choose to have higher average ticket prices and lower concession prices in consequence, as shown in Rosen and Rosenfield's (1995, p. 373) extensive theoretical analysis of ticket pricing.

The interpretation of principal components in terms of the economic forces just discussed is now reasonably clear. The eigenvector associated with the general demand component should have positive factor loadings on all prices, and should be correlated with demand shifters such as income and team winning percentage. The eigenvector associated with cost or idiosyncratic demand shifts should have oppositely-signed factor loadings on tickets and concessions, as should the eigenvector associated with price discrimination. Clearly, the pricing signatures of these two economic forces need not be distinguishable; one principal component may contain the effects of both. If so, evidence on their relative importance may be gleaned from auxiliary regressions that relate this component to costs, idiosyncratic demand shifters, and stadium characteristics that influence teams' abilities to extract consumer surplus through ticket pricing.

C. Data and Descriptive Statistics

The principal components analysis is conducted on the prices of seven goods sold by all Major League Baseball teams from 1991-2003, as reported by *TMR*: tickets (average per-game season ticket prices), official stadium parking, beer, soda, hotdogs, ballcaps, and programs. Beer and soda prices are reported for different size drinks and so are normalized to 20 ounces. All prices are converted to 2000 dollars using the Consumer Price Index. All prices are reported at the beginning of the season; promotional price changes are not included in the data.

Over this period, MLB added four teams, dramatically realigned the divisions within the American and National Leagues, introduced inter-league play, and expanded the post-season playoffs to include wild card teams. Therefore, the price data describe relatively homogenous products across all firms within an industry that has continued to evolve even while the individual firms have remained relatively isolated local monopolies. Each of these properties is conducive to testing hypotheses about multiproduct pricing.

Table 1a presents the descriptive statistics for all prices, in the upper panel, and for those variables (described further below) used in the auxiliary regressions, in the lower panel. The real price of tickets averaged $13.95 over the sample period, whereas the average real price of parking was $7.30. Prices within the stadium averaged $5.18 for a 20oz beer, $2.58 for a 20oz soda, $2.27 for a hotdog, $3.56 for a program, and $11.79 for a ball cap. The greatest variance was displayed in ticket prices, which is not surprising given the different local market and stadium characteristics across teams, and the smallest variance was in the prices of hotdogs and soda.

Table 1b reports the correlation matrix of real prices. As can be seen, the correlation between the prices of any two goods in the sample is generally positive, but never greater than 0.60. Prices are neither so uncorrelated that the goods can be viewed as having independent demands, nor so correlated that they can be treated as a single "composite good." The positive correlations suggest that the dominant influence on price is the general demand for baseball, but their modest magnitudes suggest that multiproduct pricing considerations discussed above, which introduce negative relations between prices, are also possible.

4. Pricing in Major League Baseball: Empirical Results

### *A.	Principal Component Analysis for MLB*

Table 2a presents the basic principal component analysis: the seven eigenvalues that solve the characteristic root, as well as the eigenvector and proportion of overall variation associated with each eigenvalue. The first component accounts for 40% of the total variation in real prices, with the subsequent three components accounting for approximately 15% each. The others, with very small eigenvalues and incomprehensible eigenvectors, appear to be irrelevant scree.

By carefully examining the factor loadings in these first four eigenvectors, the seven products represented can be usefully grouped into three categories: "obligatory purchases" (tickets and parking), food concessions, and non-food concessions.[6] Both goods in the first category have same-signed factor loadings in every eigenvector. Similarly, factor loadings on the three goods in the second category are consistently similar in sign and magnitude, with one small exception. In contrast, for the two non-food concessions, the signs and magnitudes of the various factor loadings are haphazard with respect to the other prices and each other.

The heuristics uncovered by the analysis can be expressed in terms of these categories. Three patterns are apparent upon examination of the factor loadings. First, the largest component has positive loadings on all prices, interpretable as a general demand effect, as before. This can include the secular trend in MLB attendance overall, interrupted by the 1994 players' strike, and intertemporal demand differences for individual teams as their performance varies over time. This variation, and the change in demand that results, is known to be substantial. This component suggests that its effect on prices is substantial as well.

Second, for each of the next three components, the factor loadings of obligatory purchases and food concessions take opposite signs but have similar sums. We can consider this the difference between the prices of these two composite goods, consistent with the other pricing influences discussed previously. This includes the interplay between complementary goods, in which idiosyncratic demand shifts or changes in concession costs increase the price of one good and decrease the price of the other, and second-degree price discrimination, in which a higher "entry fee" on obligatory purchases is coupled with lower prices for repeat-purchase food concessions.

Third, the haphazard factor loadings for the non-food concessions, along with the weak correlations between these prices and the other prices in Table 1b, suggest that the prices of these concessions are not integrated into pricing decisions for the other products. This conclusion was buttressed, on further investigation, by the discovery that the prices of caps are regulated by MLB and by informal discussions with a team official indicating that programs and food concessions are considered "separate markets" by the team, with prices determined separately for each.

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[6] Because one need not purchase stadium parking to gain access to the event, some stadiums have limited parking, and others have generous private parking, the "obligatory" nature of stadium parking is, of course, only approximate. This grouping is indicated by the analysis, however, whatever its name.

Table 2b presents results when non-food concessions are excluded from the analysis. This distills out the interplay between the five remaining prices and checks the separateness of non-food concessions: if these are excluded, the first two patterns should appear, as before. They do. General demand explains half of the combined variation in the remaining prices, and the tradeoff between obligatory purchases and food concessions about 20%. The literature suggests, variously, retaining for further analysis those components that are easily interpretable, that are suggested by theory, or that meet the "Kaiser criterion" or the "scree test." The first component meets all of these; the second fails only the Kaiser criterion, marginally; the others fail all convincingly. We thus retain the first two components for further analysis, and treat the rest as noise.

B. Principal Component Analyses for Related Markets

One simple way to check our interpretations is to conduct analogous principal component analyses of the same set of five prices in alternative markets. The first, the National Football League (NFL), is quite similar to MLB, with local monopolies that experience varying product demand selling tickets, parking, and concessions. The same forces that govern pricing in MLB should govern pricing here; thus we should expect to uncover similar factor loadings. The second market is the national market for the five most closely aligned goods for which price indexes are created by the Bureau of Labor Statistics: entertainment, parking, beer for consumption outside of the home, soda, and hotdogs. Each is converted to a "real price index" by deflating with the overall CPI. These aggregate prices, not specific to major league sports, should be set by competitive forces, not multiproduct pricing. There is no reason to expect similar loadings here; indeed, there is no reason to expect any meaningful patterns at all.

The results for these two markets, for the same 1991-2003 period, are presented in Tables 3 and 4. For the NFL, in Table 3, both the eigenvalues and eigenvectors are very similar to those uncovered for MLB. The first component, representing general demand, has positive, similar factor loadings across all prices, and explains 50% of overall price variation. The second component has oppositely-signed factor loadings on obligatory purchases and food concessions, and explains about 20% of overall price variation. The other components are small and uninterpretable.

In contrast, the eigenvalues and eigenvectors for the national market, in Table 4, are quite different. The first component, which explains 73% of price variation, includes large positive factor loadings on three prices, a small positive loading on a fourth, and a large negative loading on a fifth. This has no obvious interpretation and no relationship to the economic forces outlined previously. The second component does include positive factor loadings on tickets and parking and negative loadings on food concessions, as before, but these are dominated by an overwhelming factor loading on hot dog prices, while the others are near zero. This component essentially extracts the price of hot dogs, which does not move in concert with the other prices. This, too, does not relate to the economic forces outlined previously. In contrast, the analogous components for MLB and the NFL have substantial loadings on all prices, that sum to one for food concessions and negative one for obligatory purchases. This is easily interpretable as the difference in the prices of these two composite goods.

The analysis thus far has focused on the unexpurgated variation of real prices charged by professional sports teams, including both cross-team and cross-time variation. We believe this is appropriate; there is no reason to exclude either source of variation in advance. However, one may legitimately wonder whether price changes within teams across time exhibit similar patterns. To examine this question, we replicated the principal components analysis on prices that were purged of team and year effects, by regressing each price on a full set of team and year fixed effects and using the residuals in the analysis in the place of the original price data. By culling all nationwide and fixed-team influences from prices, we focus the analysis on local price dynamics.

In this analysis, available from the authors upon request, the principal components reveal the same qualitative relationships as those shown in Table 2b and Table 3. The largest influence on prices remained a general demand effect, which explained about 40% of the variance, and the second largest remained a price tradeoff between obligatory purchases and food concessions, which explained about 20%. Of twenty total factor loadings (2 components x 5 prices x 2 markets), nineteen were similar in sign and magnitude, with one being zero instead of the expected negative sign. These results show that our original conclusions are reasonably robust and suggest that the factors generating price variation across teams are similar to those governing local price dynamics.

Finding that the principal components are similar in a similar market, different in a different market, and robust to the purging of team and year effects lends additional credibility to our interpretations, as these outcomes would be very unlikely to occur by happenstance.

C. Auxiliary Regressions

Finally, we test our interpretations of the two (MLB) components with economic content by relating them to a common set of city, team, and stadium-specific variables that should affect prices or price interactions. Several of these are commonly included in other economic studies of professional sports: season attendance, city per-capita income, city population, once-lagged team win percentage, the age of the stadium and its square, and a dummy for whether the stadium is single-purpose. We also construct a proxy for the local wages of amusement workers.[7] The descriptive statistics for these variables, reported in Table 1b, are similar to those reported in other studies. Lagged win percentage and the wage variable are not available for first-year expansion teams and Canadian teams, so these observations are dropped.

Two models are used. Model I is sparse and direct. Attendance is used as a measure of general demand, the real wage of amusement workers as a proxy for variable costs, and a dummy for having a single purpose stadium as an indicator of the ability to price discriminate. Second-degree price discrimination should be more feasible for teams whose stadiums better permit a range of seating options and ticket prices, to better extract surplus from consumers. Single-purpose stadiums, such as Camden Yards (Baltimore), Safeco Field (Seattle), PETCO Field (San Diego), and Ameriquest Field in Arlington (TX), provide a wider variety of sight lines as reflected in their greater number of ticket options, and are thus more conducive to this pricing strategy. Attendance, which is possibly endogenous, is instrumented by the following close correlates: population, lagged income, lagged winning percentage, stadium age, and its square (see Coates and Humphreys, 2005, and Depken, 2004). Model II simply replaces attendance with these instruments. All first and second stage models also include a time trend, and both Model I and Model II are estimated using the random effects estimator, deemed appropriate vis-à-vis the fixed effects estimator or pooled OLS using Hausman specification tests.

[7] Attendance and team quality data were obtained from MLB, city income from the Bureau of Economic Analysis, city population from the Census Bureau, and stadium characteristics from Munsey and Suppes at www.ballparks.com. The real wage measure was determined using the method pioneered by Coates and Humphreys (2002), utilizing the Regional Economic Information System generated by the Bureau of Economic Analysis. These data provide the full number of employees in the service sector (all sub-sectors) and the full compensation of the amusement and entertainment sector. RWAMUSE, a proxy for the real wage rate, is measured as the total real compensation in the amusement sector divided by total service sector employment. There are some gaps in the city data and the data series ends in 2001 because of data limitations. Missing observations are imputed using city-specific interpolation/extrapolation. As the employment sector is broader than the compensation sector, the estimates of RWAMUSE are not directly interpretable, but proxy for differences in variable costs across cities and time.

The first component was associated with a general demand effect. The auxiliary regressions presented in the first two columns of Table 5 support this interpretation in two ways: by rejecting the null on variables that are associated with demand shifts and by accepting the null on variables that are not. Attendance is highly significant in Model I, while four of five instruments for attendance are significant with the expected signs in Model II. In contrast, the single purpose stadium dummy and real amusement wage are insignificant. Note, incidentally, that observed general demand shifters explain only about 60% of this component's variation, so reduced form regressions alone would vastly understate the price variation attributable to general demand shifts.

We have interpreted the second component as the difference between the prices of food concessions and obligatory purchases. This could be associated with the extent of second-degree price discrimination, negatively, as greater ability to extract surplus through ticket pricing should push down concession prices. Both Model I and Model II support this supposition, as the coefficient on the single purpose stadium dummy is significant with the expected sign. It could also be associated with variable cost increases, positively, as these should raise concession prices and lower ticket prices. This hypothesis is not supported; the coefficient on the real wage variable takes the "wrong" sign and is insignificant. Thus, the price-discrimination explanation for this component is preferred over the demand-complementarities explanation. However, given the modest fit of these regressions and the absence of idiosyncratic demand shifters in our regressions, it is possible demand complementarities still influence price interactions. Finally, general demand shifters should be unrelated to the second component. This is confirmed, as the attendance variable is insignificant in Model I, while only one of five Model II demand proxies is significant with the expected sign.

Our last set of regressions used the same models to predict the prices of programs and hats. Based on the factor loadings and price correlations, we concluded that these prices were set separately from the other prices, as if programs and hats belonged to a separate market. If so, these prices should not be closely related to our key explanatory variables. The regression results support this expectation. Other than the time trend, no coefficient is significant in any regression.

From these findings we draw three main conclusions. First, general demand shifts, only partly traceable to observables, generate roughly half of all price variation in the products sold at MLB games. This conclusion holds whether one pools all teams for all years or focuses on within-team price dynamics. Second, teams engage in price discrimination that involves a tradeoff between ticket and concession prices. Multiproduct pricing considerations contribute meaningfully to price variation in this market, but are less important than general demand shifts. Third, program and cap pricing is not integrated with the setting of other prices, partly because of price constraints imposed by MLB.

5. Conclusions

Structural analysis of multiproduct pricing is complicated by the challenge of linking prices to a large number of own- and cross-price elasticities and costs using a theoretical relationship that can be difficult to specify a priori. The principal components technique, instead, extracts information directly from the observed interactions among prices, simultaneously reducing the complexity of the analysis and broadening the scope of the conclusions that can be drawn from it.

In our examination of pricing in Major League Baseball, these conclusions are fundamental and yet new—because here, as in many other markets, the questions we address have not been previously explored, for lack of a practical way of doing so. Our analysis clusters seven goods into three categories, natural yet not obvious ex ante, whose behavior is distinct. Price variation within and across categories can be explained by elementary theory and by institutional factors. While multiproduct pricing considerations explain a non-trivial amount of price variation in this market, general shifts in product demand, driven substantially but not exclusively by variation in team success, remain the dominant influence on price.

These conclusions are of intrinsic interest, but they also inform the relevant sports economics literature. We have shown that, by accounting for demand interrelationships and engaging in price discrimination, teams' pricing methods are more sophisticated than previously modeled. The relationship between ticket and concession prices implies an omitted variables bias in the many traditional attendance studies that omit the latter, and supports previous claims that optimal ticket pricing need not require unitary elasticity of ticket demand.

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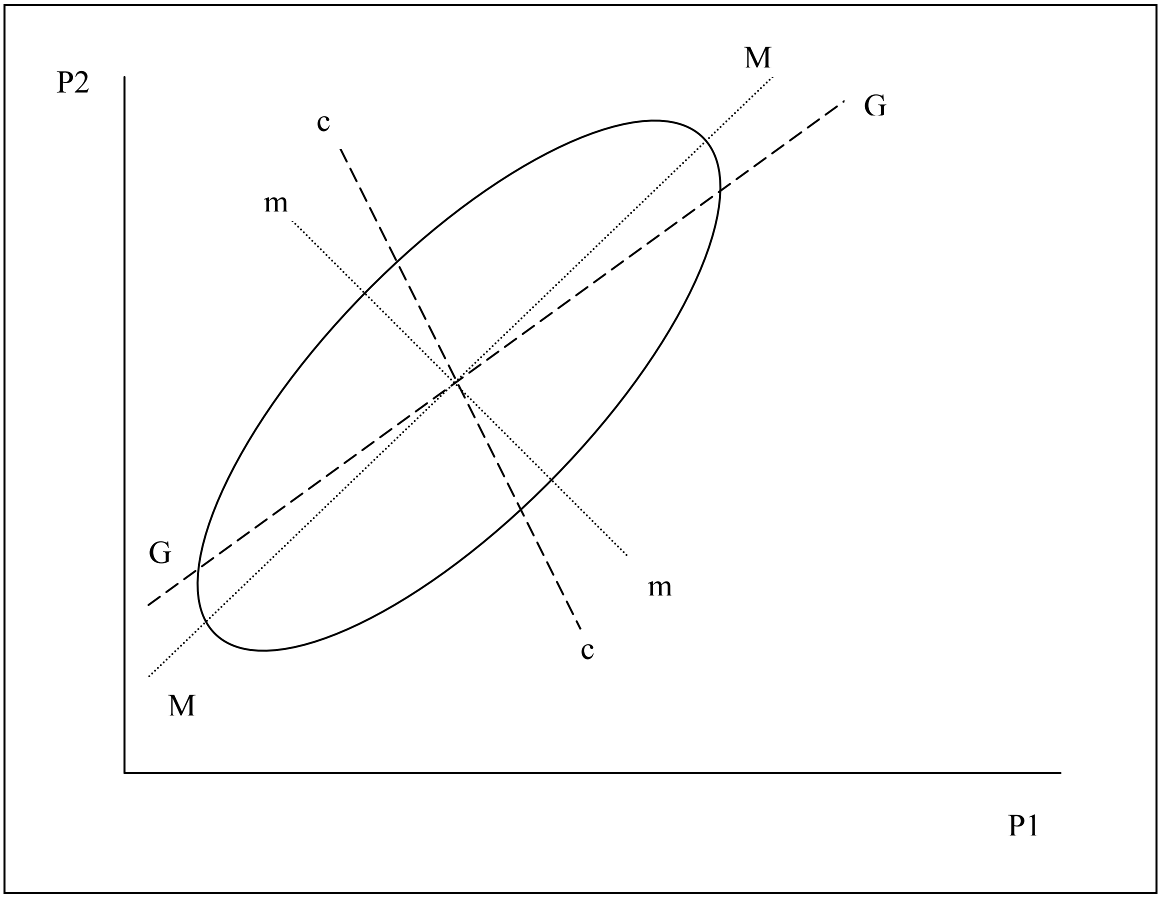
Figure 1. Simple Structural Model and Principal Components Breakdown.



Note: The ellipse circumscribes the scatterplot of realized (P1,P2) points in the (hypothetical) data. Line GG reflects the effect of changes in general demand on P1 and P2, as discussed in the text, and has a slope of β_2/β_1. Line cc reflects the effect of changes in cost, and has a slope of $-\gamma_2/\gamma_1$. Line MM, the major axis of the ellipse, reflects the first principal component. Line mm, the minor axis, reflects the second component.

Table 1a: Descriptive Statistics

Variable	Description	Mean	Std. Dev.	Min	Max
RPTIX	Average per-game season ticket price	13.95	4.51	8.29	39.83
RPARK	Price of parking	7.30	2.85	2.93	19.19
RPBEER	Price of 20oz Beer	5.18	0.92	3.19	10.57
RPSODA	Price of 20oz Soda	2.58	0.53	1.41	4.70
RPDOG	Price of hotdog	2.27	0.55	0.78	4.23
RPPROGRAM	Price of program	3.56	1.06	0.69	7.35
RPHAT	Price of ball cap	11.79	2.15	4.73	20.00
ATTEND	Total season home attendance (100Ks)	22.16	7.22	9.05	44.83
LAGINC	Previous year's MSA per-capita income ($1000s)	30.49	4.49	22.47	47.14
POP	MSA population (millions)	6.27	5.49	1.60	21.31
LAGWIN	Previous season's wins (fraction)	0.50	0.06	0.32	0.70
STAGE	Age of team's stadium in years	30.11	24.37	0.00	89.00
RWAMUSE	Real wage of amusement workers (arbitrary units)	1.20	0.38	0.58	2.34
SPURP	Team's stadium is single purpose (0/1)	0.61	0.48	0.00	1.00
TIME	Time trend (1=1991)	6.16	3.16	1.00	11.00

Price data (reported in upper panel) describe all Major League Baseball teams from 1991 through 2003 and were obtained from various issues of *Team Marketing Report (TMR)*. All prices, incomes, and wages converted to 2000 dollars using the Consumer Price Index from the Bureau of Labor Statistics. Attendance and team win percentage obtained from Major League Baseball. Population and income obtained from Census Bureau. Stadium characteristics obtained from Munsey and Suppes at *www.ballparks.com*. Wage data obtained from the Regional Economic Information System of the Bureau of Economic Analysis, as described in the text. The price data comprise a sample of 372 observations used in the principal component analysis. Stadium, income, wage, and population data are 342 observations for U.S. baseball teams (two Canadian teams not included).

Table 1b: Correlation Matrix of Real Ticket, Parking and Concession Prices

	RPTIX	RPARK	RPBEER	RPSODA	RPDOG	RPPROGRAM	RPHAT
RPTIX	1.00						
RPARK	0.59	1.00					
RPBEER	0.45	0.33	1.00				
RPSODA	0.53	0.27	0.50	1.00			
RPDOG	0.45	0.17	0.48	0.52	1.00		
RPPROGRAM	0.14	0.12	0.02	0.10	0.18	1.00	
RPHAT	0.05	-0.02	0.06	0.13	0.14	0.15	1.00

Price data describe all Major League Baseball teams from 1991 through 2003, were obtained from various issues of *Team Marketing Report (TMR)*, and were converted to 2000 dollars using the Consumer Price Index from the Bureau of Labor Statistics.

Table 2a: Principal Components of All MLB Prices: Eigenvalues and Eigenvectors

Variable	Eigenvector One	Eigenvector Two	Eigenvector Three	Eigenvector Four	Eigenvector Five	Eigenvector Six	Eigenvector Seven
RPTIX	0.49	-0.18	0.21	0.15	-0.33	-0.12	-0.73
RPARK	0.36	-0.33	0.53	0.41	0.10	-0.14	0.53
RPBEER	0.44	-0.12	-0.29	-0.04	0.80	0.21	-0.15
RPSODA	0.46	0.04	-0.26	-0.11	-0.46	0.63	0.31
RPDOG	0.43	0.20	-0.30	-0.36	-0.10	-0.70	0.24
RPPROGRAM	0.15	0.54	0.64	-0.46	0.15	0.17	-0.04
RPHAT	0.10	0.72	-0.14	0.67	0.04	-0.03	-0.02
Eigenvalue	2.79	1.14	0.98	0.80	0.52	0.46	0.31
Proportion of Variance Explained	0.40	0.16	0.14	0.11	0.07	0.07	0.04

Table 2b: Principal Components of Five MLB Prices: Eigenvalues and Eigenvectors

Variable	Eigenvector One	Eigenvector Two	Eigenvector Three	Eigenvector Four	Eigenvector Five
RPTIX	0.50	-0.30	-0.32	0.03	-0.74
RPARK	0.37	-0.74	0.07	0.15	0.53
RPBEER	0.45	0.19	0.86	-0.07	-0.14
RPSODA	0.47	0.28	-0.32	-0.71	0.31
RPDOG	0.43	0.49	-0.25	0.68	0.22
Eigenvalue	2.73	0.95	0.54	0.47	0.31
Proportion of Variance Explained	0.55	0.19	0.11	0.09	0.06

Table 3: Principal Components of NFL Prices

Variable	Eigenvector One	Eigenvector Two	Eigenvector Three	Eigenvector Four	Eigenvector Five
RPTIX	0.47	-0.43	-0.18	0.68	-0.31
RPARK	0.44	-0.55	-0.02	-0.39	0.59
RPBEER	0.38	0.63	-0.47	0.21	0.43
RPSODA	0.41	0.27	0.85	0.15	0.08
RPDOG	0.52	0.18	-0.15	-0.56	-0.60
Eigenvalue	2.50	0.98	0.67	0.44	0.41
Proportion of Variance Explained	0.50	0.20	0.13	0.09	0.08

Table 4: Principal Components of Real Price Indices

Variable	Eigenvector One	Eigenvector Two	Eigenvector Three	Eigenvector Four	Eigenvector Five
RCPITIX	0.50	-0.09	0.03	0.72	-0.48
RCPIPARK	0.50	-0.13	0.22	0.16	0.81
RCPIBEER	0.49	0.10	0.56	-0.57	-0.33
RCPISODA	-0.49	0.16	0.79	0.35	0.04
RCPIDOG	0.14	0.97	-0.15	0.09	0.09
Eigenvalue	3.65	0.98	0.16	0.13	0.08
Proportion of Variance Explained	0.73	0.20	0.03	0.03	0.02

Note: Variables are real price indices, constructed as described in the text.

Table 5: Auxiliary Regressions(coefficient estimates, with standard errors in parentheses)

Dependent Variable	Component One		Component Two		Program Price		Cap Price	
Independent Variable	**Model I**	**Model II**	**Model I**	**Model II**	**Model I**	**Model II**	**Model I**	**Model II**
ATTEND	0.99* (0.18)	---	-0.25 (0.13)	---	0.30 (0.16)	---	-0.39 (0.36)	---
POP	---	0.04 (0.03)	---	0.06* (0.02)	---	0.03 (0.02)	---	0.05 (0.05)
LAGINC	---	0.09* (0.02)	---	-0.03 (0.02)	---	-0.02 (0.02)	---	-0.04 (0.05)
LAGWIN	---	2.64* (0.82)	---	-0.47 (0.53)	---	0.75 (0.53)	---	0.23 (1.64)
STAGE	---	-0.04* (0.02)	---	0.03* (0.01)	---	-0.01 (0.01)	---	0.03 (0.02)
$STAGE^2/100$	---	0.05* (0.01)	---	-0.04* (0.02)	---	0.00 (0.01)	---	-0.03 (0.03)
SPURP	0.43 (0.22)	0.34 (0.24)	-0.65* (0.15)	-0.46* (0.17)	-0.37 (0.19)	-0.47 (0.25)	0.20 (0.38)	-0.25 (0.44)
RWAMUSE	0.01 (0.26)	0.23 (0.24)	-0.08 (0.17)	-0.33 (0.18)	-0.03 (0.22)	-0.17 (0.25)	0.02 (0.44)	-0.38 (0.50)
TIME	0.25* (0.02)	0.20* (0.02)	0.03* (0.01)	0.05* (0.02)	0.12* (0.01)	0.11* (0.02)	0.08* (0.03)	0.12* (0.05)
R^2	0.48	0.68	0.06	0.26	0.19	0.22	0.01	0.02
Wald (X^2_9)	655.9*	775.93*	39.65*	63.8*	120.1*	128.1*	8.3	12.2

Note: N = 342: Canadian teams and first-year expansion teams are excluded because the lagged winning percentage or real wage cannot be measured. A random effects estimator was applied after Hausman specification tests. The first two principal components from Table 2b are the dependent variables, along with the real prices of programs and hats. * indicates significance at the 5% level in a two-tailed test.