Game Theoretic Pricing Models in Hotel Revenue Management: an equilibrium choice-based conjoint analysis approach

Abstract

This paper explores a game-theoretically founded approach to conjoint analysis that determines equilibrium room rates under differentiated price competition in an oligopolistic hotel market. Competition between hotels is specified in terms of market share functions that can be estimated using multinomial logit models of consumer choice. The approach is based on choice-based conjoint analysis that permits the estimation of attributes weights ("part-worths") for an additive utility formulation of the utility function. From this, room rates that equilibrate the market, conditioned on the differences in services and facilities offered by competing hotels, can be determined. The approach is illustrated by an example.

Keywords

Game Theory; Equilibrium; Conjoint Analysis; Discrete Choice, Pricing; Price; Revenue Management; Hotel; Room, Attributes

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1. Introduction

Pricing is perceived to be one of the most difficult marketing decisions in hotel management practice (Dutta, Zbaracki & Bergen, 2003; Van der Rest, 2006; Johansson, Hallberg, Hinterhuber, Zbaracki & Liozu, 2012). It is variously seen as: the centerpiece of strained customer relationships, a strategy used to steal market share, and a source of intra-company conflict. Not unexpectedly, pricing tops the list of problematic issues in marketing (Dolan & Simon, 1996). Moreover, behaviors such as price collusion, deceptive price advertising, and predatory pricing have enormous impacts on consumer welfare. 'It is not surprising then that a great deal of government legislation and judicial decision making focuses on the pricing behavior of firms' (Grewal & Compeau, 1999, p.3). Over the years, pricing has attracted research in the areas of economics, law, accounting, marketing, operations research, and more recently strategic management (Van der Rest & Roper, 2013). Much of this work utilizes some degree of economic analysis.

Economic analysis of price is founded on the notion of equilibrium (Bridel, 2001). Through time the concept of equilibrium has received both academic and practitioner criticism. As early as Edgeworth (1881), doubts were casted about the stability of equilibria. Von Hayek (1937, pp. 43-44) stated: 'the only justification for this is the supposed existence of a tendency toward equilibrium […] an exercise in pure logic'. Game theoretic models of oligopoly pricing accommodate an embarrassingly rich set of equilibria, which cannot all be mapped in terms of observables to patterns actually observed in markets (Vives, 1999). Comparative studies spanning different types of markets have led to the conclusion that the concept of equilibrium has only limited validity in the real-world (Fog, 1994).

In the field of hospitality a number of equilibrium pricing models have been proposed, with notable contributions from Baum and Mudambi (1995), Chung (2000), Friesz, Mookherjee and Rigdon (2005), Gu (1997), Ling, Guo and Liang (2011), Pan (2006), Schwartz (1996), Song, Yang and Huang (2009), Wachsman (2006), and Yang, Huang, Song and Liang (2008). However, this body of knowledge suffers from some obvious limitations from a hotel marketing and business practice perspective, in as much as it relies on conventional price theory – 'both as a paradigm for guiding theoretical model development and as a conceptual framework for steering empirical efforts' (Diamantopoulos & Mathews, 1995, p.19). Pricing in practice is '*much* more complex than *any* theoretical perspective suggests' (Diamantopoulos, 1991, p. 166). As Gijsbrechts (1993, p.117) laments, commenting on Tellis' (1986) unifying taxonomy of the many pricing strategies described in the literature: 'as a "simple" integrative scheme, [the approach] can provide only an indirect treatment of some important issues […] In real life, a manager may […] face the problem of combining various principles into one set of pricing rules.' As Bonoma, Crittenden and Dolan (1988, p.359) argue, 'it seems that academic researchers have not known, or do not focus on, the key pricing concerns of managers in order to conduct rigorous pricing research'. In the words of Cressman (1999, p.456) who observes an overreliance on neoclassical price theory whilst reviewing Noble and Gruca's (1999) proposal to integrate existing theoretical pricing research into a new two-level framework for pricing strategies: 'why are there no pricing practices based on the value delivered to customers in the marketing literature?'

Conventional price theory does not offer practical decision rules by which hotels can make actual price decisions in practice. Theory's task has been to explain certain (rational) decisions or outcome, 'excluding or holding constant many real variables that are not germane to its theoretical objectives' (Nagle, 1984, pp.3-4). Neoclassical economics focuses on the distal end *state* or equilibrium (outcome) of the process by which prices are formed. No reference is made to the behavioral decision *process* by which hotels arrive at prices. And yet, economic theory does provide 'useful heuristics for understanding the consequences of action' (Nagle, 1984, p.4). Concepts and insights, analytical methods, and models can be brought to bear on various practical pricing decisions. Ultimately, hotel pricing policy is the task of marketing and revenue management. As Hauser (1984, p.65) states: 'in the extreme, price theory in economics deals with how markets behave, while price theory in marketing science deals with how managers should act'.

Economic analysis is not the only approach to optimizing prices and revenue. In recent years a whole body of work founded on the well-established tradition of operations research, and not constrained by the limitations of the economic equilibrium paradigm has developed, gaining a strong track record in practical applications (e.g. Pekgün et al., 2013). This field of pricing and revenue management, as reviewed comprehensively in, for example, Weatherford and Bodily (1992), McGill and Van Ryzin (1999), Elmaghraby and Peskinocak (2003), Bitran and Caldentey (2003), and Talluri and Van Ryzin (2004), is less restrictive in theoretical assumptions. The approach uses methodologies – predominantly stochastic programming and simulation – to address complex optimization problems in perishable asset revenue management (PARM), taking into account, inter alia, how pricing is affected by demand uncertainty and forecasting errors (e.g. Yüksel, 2007), demand learning (e.g. Den Boer & Zwart, 2014). Applications include the problem of multiple-night stays (Aslani et al., 2013) and upgrades (Gönsch et al., 2013). Whilst game theoretic models in economics predict prices resulting from the dynamic interaction of competitors, such models are unable to incorporate the range of real-world problems that are addressed in the PARM literature. A melding of these different perspective is much needed.

With a view to bridging the gap between theoretical and methodological perspectives of economics and marketing science in the context of hotel revenue management in operations research, this paper explores the potential benefits of integrating conjoint analysis, a statistical technique originating from mathematical psychology, with game theory. We build on Choi and DeSarbo (1993) who propose a mathematical programming approach for *product* optimization, incorporating competitors' reactions in a game theoretic structure. But, rather than finding the specific set of multi-attribute product alternatives that constitute an equilibrium, this paper focuses on the equilibrium *price* for each of the competitors, conditioned on the differentiated product attributes and prices offered by all competitors. As the essence of equilibrium pricing among hotels in a local market is differentiated price competition, we use differentiated Bertrand competition as the oligopoly model. Each hotel’s profit is driven by its market share which, in turn, is defined as a function of the hotel's own price, and non-price attributes (such as quality, location, and service level), as well as its competitors' price and non-price attributes. It is obvious that hotels with a superior offering on non-price attributes generate customer value which justifies a higher price compared to competing hotels with a lower levels of non-price attributes. Obviously, market prices of hotels may be markedly different from each other in equilibrium (i.e. no hotel has an incentive to change its price, cet. par.). To incorporate the preferences of potential guests over attributes, the market share is operationalized through a discrete choice model, the parameters of which can be estimated using choice-based conjoint analysis.

This paper extends Choi and DeSarbo (1993). First of all, it utilizes a choice-based conjoint approach instead of a traditional full profile conjoint approach, which not only brings the model up to date with contemporary standards in conjoint analysis, but more importantly enables the use of the "none-option" in the choice set, making the model more realistic. This is a crucial step towards increasing the practical applicability of equilibrium pricing. Secondly, the model focuses on determining price, which is treated as the only (continuous) choice variable, and treats the other (non-price) attributes as fixed. This is in contrast to the approach by Choi and DeSarbo (1994) where multiple attributes can be optimized over discrete sets.

In this way, the paper specializes the general framework of Choi and DeSarbo (1993) for pricing in the hotel service sector. It seeks to make a beginning in connecting the (oligopoly) pricing literature with contemporary work in revenue management from the field of marketing science and operations research. This should introduce a new perspective to the long-lasting discussion on whether discounting in the lodging industry works (Abbey, 1983; Croes & Semrad, 2012; Enz, Canina & Van der Rest, 2015; Hanks, Cross, & Noland, 1992, 2002; Kimes, 2002, Van der Rest & Harris, 2008), and whether and to what extent differentiation can protect hotels from the pressure to reduce prices (Becerra, Santaló & Silva, 2013).

2. Towards a Managerial Framework

The routines involved in setting room rates for a hotel can be viewed as choices made in a strategic game where the players are the revenue managers of the hotels in the given market. The payoffs are the revenues resulting from price combinations, and the players' strategies are the room prices, chosen to optimize hotel revenues. In this game the payoffs are continuous functions of the choice variable (*i.e.* revenue, a function of price). If total market demand is assumed to be fixed in the short-term, then a very general payoff function for the revenue manager of hotel *i* in a market with two hotels (*i* and *j*) may be written as:[1]

$$\mathrm{R_i} = \mathrm{DM_i}\left(\mathrm{P_i}|\mathrm{P_j},\mathrm{X_i},\mathrm{X_j}\right)\mathrm{P_i}, \qquad (1)$$

where:

$\mathrm{R_i}$	= revenue for hotel i
D	= total market demand
$\mathrm{P_i}$	= room price charged by hotel i
$\mathrm{P_j}$	= room price charged by hotel j
$\mathbf{X_i},\mathbf{X_j}$	= vectors of non-price attributes offered by hotel i and j respectively

[1] The results developed hold true for any number of players without loss of generality. 'Hotel i' and 'the revenue manager of hotel i' are used as interchangeable identifiers.

$M_i(P_i|P_j, \mathbf{X}_i, \mathbf{X}_j)$ = market share for hotel i as a function of room prices charged and the non-price attributes offered by hotels i and j

This payoff function represents the total payoff that hotel *i* will obtain from its strategy: defined as setting room price at level P_i. The market share of hotel *i* depends on both its own price and the price set by the competitor, conditional on the fixed non-price attributes of hotel *i* and *j*. Note that total market demand is assumed to be fixed in the short term.

If the revenue managers of hotels *i* and *j* act rationally given their payoff functions, a Nash equilibrium-price profile can be determined from the system of equations where the first derivatives of the revenue functions with respect to the choice variable price, is equal to zero. That is:

$$\frac{\partial R_i}{\partial P_i} = P_i \frac{\partial M_i(P_i|P_j, X_i, X_j)}{\partial P_i} + M_i(P_i|P_j, X_i, X_j) = 0, \tag{2}$$

and,

$$\frac{\partial R_j}{\partial P_j} = P_j \frac{\partial M_j(P_i|P_j, X_i, X_j)}{\partial P_j} + M_j(P_i|P_j, X_i, X_j) = 0. \tag{3}$$

Solving the system of equations (2,3) for P_i and P_j gives the optimal (revenue-maximizing) prices for hotels *i and j*. Buyers typically respond to price and non-price differences, and revenue managers make price decisions with due consideration to the prices that opponents charge, given the degree of vertical and horizontal differentiation in their geographical area (Becerra, Santaló & Silva, 2013). Equations

(2) and (3) define the best reactions of each hotel to the price set by the other, and together define a unique Nash equilibrium in pure strategies. The standard implication is that neither hotel has an incentive to change room price unconditionally, because that would always result in a decrease of revenue.

In reality hotels dynamically change prices back and forth and room prices track time varying equilibria. Real-world hotels have to deal with limited information, time-pressured decision making, cognitive limitations of the mind, and inter-organizational politics (Hague, 1971). The motivation for the notion of bounded rationality as an alternative basis for decision-making (Simon, 1957) and for the use of heuristics as the basis for human decision making (Kahneman & Tversky,1979) are clear.

3. Operationalization of Market Share

A convenient and very general way of modeling market share is by use of the multinomial logit model (MNL). In applied choice analysis the MNL model of individual consumer decision making is expressed as:

$$\Pr(Y_q = i) = \frac{\exp(U_{qi})}{\exp(U_{qi}) + \exp(U_{qj})}, \tag{4}$$

where:

$\Pr(Y_q = i)$ = the probability that consumer[2] q will choose i from a set {i,j}

U_{qi} = utility that consumer q associates with alternative i

U_{qj} = utility that consumer q associates with alternative j

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2 In the context of MNL (in formula 4) the decision-maker is the consumer (i.e. hotel guest), as opposed to formula's 1, 2 and 3 in which the player in the game is the hotel (i.e. revenue manager).

Formula (4) can be derived under quite general conditions from the assumption that consumer *q* will choose the option *i* from a set {i,j} if and only if:

$$U_{qi} + \varepsilon_{qi} > U_{qj} + \varepsilon_{qj}. \tag{5}$$

Here, utility has the conventional economic connotation of satisfaction that hotel guest *q* derives for room *i*. The MNL model choice rule in (4) is derived from (5) under rational choice and the additional assumption that the errors $\{\varepsilon_{qi}, \varepsilon_{qj}\}$ are distributed i.i.d., Extreme Value Type 1.[3]

Under homogenous consumer preferences over attributes the market share of a hotel room can be viewed as the probability that a "representative" guest chooses that room from the set of available hotel rooms. If this assumption is reasonable, then $\Pr(Y_q = i)$ might be replaced by the market share of i, M_i, and consequently (4) becomes:

$$M_i = \frac{\exp(U_{qi})}{\exp(U_{qi}) + \exp(U_{qj})}. \tag{6}$$

The utility in (6) is no longer conceptualized as the subjective satisfaction of an individual consumer, but instead as that of an "average" consumer in the market.[4]

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3 See McFadden (1974) and Louviere, Hensher and Swait (2001, pp 37-47) for a full derivation of equation (4).

4 In practice, revenue managers can use statistical techniques such as choice-based conjoint analysis to estimate U_qi and U_qj from a set of representative behavioral data. Note that the dynamics of (6) are intuitively plausible: market share for a hotel room increases when it becomes more desirable or when a competitors' hotel room becomes less desirable, and vice versa. Furthermore, market share is constrained

Thus far, the behavioral model is similar the pioneering work of Choi and Desarbo (1993). One advance follows from adding a so-called “no-choice option” to the model. As can be seen from the formulation in (6) the model is fairly restrictive in the sense that the hotel guest is forced to make a choice between the available options, without the freedom to choose an option outside the choice set or to choose no hotel room at all. It is reasonable to expect that a guest might want to defer her choice if neither of the room options available is good enough. In line with (5) it can be assumed that a specific option is chosen only if its utility exceeds a certain utility threshold, that is, only if:

$$U_{qi} + \varepsilon_{qi} > N_q + \varepsilon_{qn}, \tag{7}$$

where N_q is the threshold utility for choice by hotel guest q in a given market (also called the “no-choice utility”). The no-choice option implies the decision to not book a hotel room at all, or the decision to postpone a choice to some future point in time (when the prospect of obtaining a desirable room price combination is more favourable). In the latter case the no-choice option reflects an aggregate measure of ‘desiredness’ of the competing room offerings that exist outside the current choice occasion.

The inclusion of the no-choice option in discrete choice models enhances the applicability of the game-theoretic model. If the competition between two or more hotels is modeled without a no-choice alternative then every guest would be forced

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to lie within the <0, 1> interval. It can thus be argued that (6) provides a well-behaved and plausible model of guest choice within a competitive context.

to make a choice between the two hotels no matter how high the prices actually become. The optimal prices $\{P_i^*, P_j^*\}$ would be determined by solving (2) and (3), and without a constraint on total market demand this would leave open the potential for a collusive equilibrium with both hotels raising their prices. Whilst the approach of Choi and Desarbo (1993) may provide a reasonable assumption in some oligopolistic markets (*e.g.* gasoline), it is unrealistic for hotel markets with their fragmented structure, where it is unlikely that all hotels available to the potential guest can be included in a choice model. This is in part because of the high degree of differentiation, and cartel-like restrictions on entry (Scherer & Ross, 1990). The inclusion of a no-choice option is thus necessary in order to model the price formation process in (capacity constrained) hotel markets realistically. By their very nature, hotel markets offer an almost unlimited number of choice alternatives available (*e.g.* venues, locations, substitutes, postponement).[5]

4. Using Conjoint Analysis to Measure the Utility Contribution of Attributes

With a general structure for the competition between the revenue managers that allows for the no-choice alternative in place, the product-level utilities can be specified using an additive utility model (Fishbein, 1967). For convenience suppressing the index q denoting the consumer:

$$U_i = \sum_{k=1}^{K} B_k X_{ki} + AP_i \tag{8}$$

where:

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5 Because Choi and DeSarbo (1994) used the traditional full profile rating/ranking conjoint analysis method, they were unable to estimate a no-choice utility (i.e. a choice-based conjoint analysis or any other discrete choice analysis procedure is needed for this).

X_{ki} = dummy variable indicating the presence of an attribute level k from a set of K attribute levels in hotel i

B_k = the marginal utility associated with attribute level k

A = the marginal (dis-)utility associated with the price attribute

That is, *K* attributes are postulated by the revenue manager as being relevant to consumer utility from hotel rooms. Hotel *i* can then described by an vector consisting of K non-price attributes and price, represented as $\{X_{ki}, P_i\}$. The corresponding vector of parameters $\{B_k, A\}$,[6] which apply to the representative consumer, can be estimated by applying (choice-based) conjoint analysis to stated choice market research data, or discrete choice analysis to observed choice data.

In the simplest textbook model, *K* is set to equal 1, with room price the only relevant attribute. Then the conditions (2) and (3) that jointly define the equilibrium can be derived with only the room rates of the hotels *i* and *j*.[7] It will be much more realistic if other room attributes are allowed for in the utility function - for example, value attributes such as the usage and exclusion rights over room and hotel facilities, or public domain attributes such as distance to the center (Alegre, Cladera & Sard, 2013; Andersson, 2010). Allowing such non-price attributes to the utility function is useful from the point of view of applicability of results. It allows for differentiated price competition between hotels where higher prices might be sustained by higher quality or other desirable characteristics.

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[6] Note that the use of the MNL model for the market share formation precludes the inclusion of a constant in the utility function. The MNL model is invariant under the addition of a single constant to every player's utility function.

[7] The level of market demand D is irrelevant to the location of the equilibrium.

Conjoint analysis offers a very natural way of measuring the weight that hotel guests attach to different attributes associated with certain hotel service product dimensions and it can be used to fill in the $\{B_k, A\}$. This completes the theoretical model formulation as in equation (9):

$$P_i \frac{\partial \frac{\exp\left(\sum_{k=1}^{K} B_k X_{ki} + AP_i\right)}{\sum_{j=1}^{I} \exp\left(\sum_{k=1}^{K} B_k X_{ki} + AP_i\right)}}{\partial P_i} + \frac{\exp\left(\sum_{k=1}^{K} B_k X_{ki} + AP_i\right)}{\sum_{j=1}^{I} \exp\left(\sum_{k=1}^{K} B_k X_{ki} + AP_i\right)} = 0 \quad \forall \quad i \in I\,, \qquad (9)$$

With the parameters obtained from the estimated conjoint model, this system of equations can be solved to obtain the equilibrium vector of prices.

5. Illustration

In this section we demonstrate the methodology in the context of a fictitious island resort industry. An island is particularly suited for this purpose as it has a small number of hotels and a relatively homogenous market (Baum & Mudambi, 1995). The objective is to illustrate how equilibrium prices can be determined for three upscale but different hotels given their oligopolistic interaction.

The first step is the choice-based conjoint experiment. Location, overall customer rating, and swimming pool facility are used as non-price attributes (e.g. Callan & Bowman, 2000; Fleischer, 2012; Rigall-I-Torrent et al., 2011; Suh & McAvoy, 2005). A none-option is also included. The next step is to fit a basic MNL model with simple additive utility to the experimental data (formulas 5 through 9). Table 1 presents the estimated coefficients (*i.e.* “part-desirednesses”) of such a model.

INSERT TABLE 1 HERE

In this model, location, customer rating, and swimming pool facility are coded as dummy variables, with the least attractive level coded as the base (0). Price is coded as a scale variable (*i.e.* the partial utility of a price at level X enters the utility function in (8) through a linear function of X.).[8] The coefficients in table 1 are reasonable under the assumption that the average guest prefers ocean view over downtown, a 5-star over a 4-star customer rating, a swimming pool over no swimming pool, and lower prices over higher prices. The value of 1 for "None" reflects the tendency of guests not to choose any of the resort hotels available when none are acceptable to them.

The third step is to set out the hotel's market share functions as described by formula 6. If the hotels are indexed by i=1,2,3, where i=1 is a 5-star rated ocean view hotel without swimming pool, i=2 is a 4-star rated ocean view hotel with swimming pool, and i=3 is a 5-star rated downtown hotel with swimming pool. Then their respective market share functions would be:[9]

$$M_1(P_1,P_2,P_3) = \exp(2{,}75+2{,}25+0-0{,}005P_1)/(\exp(2{,}75+2{,}25+0-0{,}005P_1)+\exp(2{,}75+0+1{,}75-0{,}005P_2)+\exp(0+2{,}25+1{,}75-0{,}005P_3)+\exp(1{,}0)) \quad (10)$$

8 The model can easily be adapted to handle non-linear relationships and interactions as well.

9 Note that by inclusion of a none-option the {Mi} no longer refer to "market shares" in a strict sense as market shares, by definition, sum to one over the players only. Instead, the {Mi} sum to one over the players plus the no-choice option. Nonetheless, for the sake of clarity the {Mi} shall still be referred to as market shares.

$M_2(P_1,P_2,P_3) =$ $\exp(2{,}75+0+1{,}75-0{,}005P_2)/(\exp(2{,}75+2{,}25+0-0{,}005P_1)+\exp(2{,}75+0+1{,}75-0{,}005P_2)+\exp(0+2{,}25+1{,}75-0{,}005P_3)+\exp(1{,}0))$ (11)

$M_3(P_1,P_2,P_3) =$ $\exp(0+2{,}25+1{,}75-0{,}005P_3)/(\exp(2{,}75+2{,}25+0-0{,}005P_1)+\exp(2{,}75+0+1{,}75-0{,}005P_2)+\exp(0+2{,}25+1{,}75-0{,}005P_3)+\exp(1{,}0))$ (12)

In order to specify (2) we also need the first derivatives of these functions with respect to P_i which are given by:

$P_1 \times M_1(P_1,P_2,P_3) \times (1-M_1(P_1,P_2,P_3))$, (13)
$P_2 \times M_2(P_1,P_2,P_3) \times (1-M_2(P_1,P_2,P_3))$, (14)
$P_3 \times M_3(P_1,P_2,P_3) \times (1-M_3(P_1,P_2,P_3))$. (15)

Together, equations (10) through (15) provide the inputs to set up the equilibrium conditions in terms of the first derivatives of the payoff functions with respect to P_1, as described in (2), that is:

$P_1 \times (P_1 \times M_1(P_1,P_2,P_3) \times (1-M_1(P_1,P_2,P_3))) + M_1(P_1,P_2,P_3) = 0$, (16)
$P_2 \times (P_2 \times M_2(P_1,P_2,P_3) \times (1-M_2(P_1,P_2,P_3))) + M_2(P_1,P_2,P_3) = 0$, (17)
$P_3 \times (P_3 \times M_3(P_1,P_2,P_3) \times (1-M_3(P_1,P_2,P_3))) + M_3(P_1,P_2,P_3) = 0$, (18)

with the $\{M_i(P_1,P_2,P_3)\}$ as previously defined in (10) through (12). In order to solve this system of equations and find the values $\{P_1^*,P_2^*,P_3^*\}$, a modified Newton-Raphson procedure can be implemented.[10] For ease of calculation, it is suggested

[10] This is an iterative algorithm to estimate the root of a function (i.e. the value X at which f(X) evaluates to zero) by using the updating formula (Burden & Faires, 2005, p.65): $X_{t+1} = X_t - f(X_t) / f'(X_t)$, (19) where $f(X_t)$ is the

that the the first derivatives of (16) through (18) are approximated by calculating the relevant gradient by forward finite differencing. The final estimation algorithm thus becomes:

Step 1: Set initial values at say P_1= 150, P_2=200, P_3=175. Set step size for finite differencing at k=0.01.

Step 2: Calculate the left hand sides of (16) through (18) and store these values as vector V_1.

Step 3: Increase $\{P_1,P_2,P_3\}$ by step size k.

Step 4: Calculate the left hand sides of (16) through (18) and store these values as vector V_2.

Step 5: Approximate the first derivative of (16) through (18) as: $(V_2-V_1)/k$ and store as vector V_3.

Step 6: Update $\{P_1,P_2,P_3\}$ based on the Newton-Raphson formula in (19, see footnote 10) using V_1 and V_3.

Step 7: Repeat step 2 through 6 until $\{P_1,P_2,P_3\}$ converge to the equilibrium prices at {340,293,259}.

The algorithm described above typically converges within about 30 iterations and is very easy to implement in a standard spreadsheet program. Although the algorithm is stable under varying starting conditions, it should be repeated from multiple starting points in order to confirm the results.

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function of which the root is to be found, in this case being (16) through (18), and f'(Xt) is its first derivative with respect to Xt.

The resulting prices {340,293,259} are the equilibrium room rates for the two ocean view hotels and the downtown hotel. A property of the (Nash) equilibrium is that unilateral price changes by any of the hotels will always lead to a lower revenue. Note that the room rate prices {340,293,259} constitute a differentiated price competition equilibrium. Hotel i=1, with its ocean view and 5-star rated overall quality but no swimming pool can sustain a premium price at €340 per night. The second ocean view hotel, although having a 4-star rating, but with a swimming pool and can only sustain a charge of €293 per room. Finally, the downtown hotel with 5-star customer rating and swimming pool has to settle for the lowest room rate of €259. The additive utility formulation within the conjoint model guarantees that all these elements are weighted appropriately in order to arrive at the equilibrium prices.

6. Discussion and Implications

This paper presents an equilibrium framework for the determination of hotel room prices, building on the foundations of an oligopoly game. Each hotel optimizes its individual revenue function by setting its price, conditional on the non-price features, as well as the prices and non-price features of all competing hotels. The hotel revenue functions are linked together through the market share functions, with each hotel's market share determined jointly by the offerings of all competing hotels in terms of room prices *and* non-price attributes. Choice-based conjoint analysis is proposed as the means of measuring the relative weights (part-worths) consumers assign to non-price attributes. In this way, the paper contributes to the choice-based conjoint analysis approach in Choi and DeSarbo (1993), by allowing for the "none-option" whereby consumers are permitted to defer / postpone purchase, when none of the options are above some minimal utility threshold. This is obviously important from a behavioral perspective. It is also important from the perspective of tractable modelling, as most hotel markets of interest will be populated by too numerous a set of players to be all included in the model together. Allowing the none-option makes it possible to analyze competitive outcomes for meaningful subsets of competitors, while not allowing the none-option can lead to multiple equilibria (Soberman, Gatignon & Sargsyan, 2006). Moreover, by focusing on price as the single choice variable that is conditioned on other fixed (discrete) attributes, this paper refocuses attention on the applicability of game theory based choice modeling in marketing science and operations research. We thus attempt to contribute to 'the age of "pluralism" in which methodologists, economic modelers, and consumer behaviorists will live side by side and learn from one another' (Green, 2004, p.241). Integrating conjoint analysis with game theory extends the scope of choice modelling in revenue management. For example, based on a conjoint experiment and using latent class analysis it will be possible to establish distinct market segments (e.g. in behavioral terms 'deal seekers' or 'luxury seekers'), each of which yielding their own utility parameters which can be put into the pricing model in order to generate segment-wise equilibria.[11]

There are some limitations to the model that should be acknowledged. The first is the issue of practical applicability. Can any game theoretic pricing framework which assumes that competitors act rationally and have complete information address the dynamics of competition in the international hospitality industry? Although the model's primary contribution is to provide guidelines for rational decision making, the question remains whether the model can predict market

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[11] There will be, however, significant challenges from a model estimation point of view.

outcomes. Empirical work in this area by Putsis and Dhar (1998) and Roy, Hanssens and Raju (1994) offers fruitful directions for future research in this area. Second, questions may be raised about the validity of the behavioral assumptions underpinning the multinomial logit (MNL) choice model -- 'Independence from Irrelevant Alternatives' (IIA) and homogeneity of tastes. Under IIA, 'the presence or absence of an alternative in a choice set preserves the ratio of the probabilities associated with the other alternatives in that choice set' (Louviere, Hensher & Swait, 2000, pp.160-162). This is restrictive: for example, will a new hotel that opens next door to a virtually identical *existing* hotel, draw its' clientele equally from both its neighbor and a 2-star hostel three blocks down the road? Equally, the MNL assumption that all consumers share the same average taste weights $\{B_i, A\}$ is restrictive. It is known that MNL parameter estimates are biased if taste weights are heterogeneous in actual fact.[12] A number of alternative specifications that relax the above assumptions have been suggested, including Nested Logit, Mixed Logit, Probit and Hierarchical Bayes approaches. These rely on explicit structures for the error covariance matrix of the respondents' utilities (taste heterogeneity), non-IIA utilities or both. These approaches generally lack closed-form expressions, and simulation-based approaches are needed for estimation and forecasting. Third, the results may be different, and the analysis considerably more complex if the optimization problem allows for variable demand. Similarly, replacing revenue-optimization objective with profit-optimization will present a challenge as the necessary additional input (i.e. cost information) is often hard to come by. Finally, hotels may engage in dynamic pricing over the booking horizon, with lower prices offered to guests who book long before they arrive, relative to those who book near

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[12] See for example Louviere et al. (2000, pp. 138-212) for many examples of this.

the day of arrival. The basic MNL framework does not have time-dependent parameters. Also, there is the problem of capacity constraints. The MNL model assumes that any demand that is generated for a particular hotel can be fulfilled. In reality a hotel may not have sufficient number of rooms available to satisfy demand. When a hotel 'sells out', the set of alternatives available to the remaining customers change. These dynamics will be even more complicated with taste heterogeneity, as then the order in which hotels fill up will be determined by the order in which customers with particular tastes enter the booking process. Addressing the above issues are outside the scope of this paper, but they set out an agenda for future contributions in applying conjoint analysis and discrete choice modeling in the hospitality (revenue management) research.

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