Reservation Price Estimation by Adaptive Conjoint Analysis

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Abstract. Though reservation prices are needed for many business decision processes, e.g., pricing new products, it often turns out to be difficult to measure them. Many researchers reuse conjoint analysis data with price as an attribute for this task (e.g., Kohli and Mahajan (1991)). In this setting the information if a consumer buys a product at all is not elicited which makes reservation price estimation impossible. We propose an additional interview scene at the end of the adaptive conjoint analysis (Johnson (1987)) to estimate reservation prices for all product configurations. This will be achieved by the usage of product stimuli as well as price scales that are adapted for each proband to reflect individual choice behavior. We present preliminary results from an ongoing large-sample conjoint interview of customers of a major mobile phone retailer in Germany.

1 Introduction

Pricing products is a difficult task for every business. Thorough knowledge of the demand in the market is necessary to predict the different effects that arise from the pricing strategy as well as from the set price for a product: Customer switching effects, cannibalization effects, and market expansion or contraction effects. Many of these effects can be analyzed for different strategies using the reservation prices of the participants in the market (Jedidi and Zhang (2002)). Varian (p. 4, 2003) defines the reservation price as follows:

> The reservation price is the highest price that a given person will accept and still purchase the good. In other words, a person's reservation price is the price at which he or she is just indifferent between purchasing or not purchasing the good.

However, this definition is different from the definition of reservation price used by other authors. For example, Kohli and Mahajan (1991) define the reservation price for their study as the price for a product such that an individual switches away from her most preferred product. To our knowledge

Jedidi and Zhang (2002) are the only researchers who have applied the economic definition of reservation price in combination with a conjoint study on product pricing.

In this paper we present a novel approach to estimate the economic reservation price using the popular conjoint analysis. We do not incorporate price as an attribute in the conjoint analysis but we introduce price by an additional choice-based scene after the conjoint analysis. The paper is organized as follows: In section 2 we identify shortcomings of the estimation of reservation prices using only data from conjoint analysis. In section 3 we present our novel approach and its foundation in economic theory. In section 4 we outline an application of the method for a mobile phone retailer. We conclude with a short discussion of further research.

2 Conjoint Analysis for Reservation Price Estimation

Conjoint analysis and especially adaptive conjoint analysis (ACA) (Johnson (1987)) is a popular tool in marketing research to survey consumers' preferences for products that are seen as the combination of several attributes which have different levels. With conjoint analysis utility-scores for the attribute levels are estimated that reflect the respondents valuations of the inclusion, exclusion or degree of the levels.

The major approach in pricing studies by conjoint analysis is incorporating the price as an additional attribute (e.g., Green and Srinivasan (1990), Orme (2001)). The attribute price is then assigned a part-worth utility as the other attributes and some interpolation heuristics are applied. To estimate reservation prices several studies using conjoint data are found in the current literature (e.g., Kohli and Mahajan (1991), Jedidi and Zhang (2002)). In these studies authors try to estimate reservation prices from previously acquired conjoint data which include price as an attribute. However, these approaches have the following shortcomings:

1. Conjoint analysis only measures the preference structure for the analyzed product configurations. If the individual would really purchase at a given price is not elicited. Therefore, reservation price in an economic sense cannot be measured.
2. The *number-of-levels* and the *range* effect are well-known in conjoint analysis (Verlegh et al. (2002)). If the number of attribute levels or the range covered by the attribute levels is increased by the researcher, the perceived importance of that attribute also increases. These effects are especially problematic for pricing studies in which often a large number of different prices is surveyed.

In the following we address these issues by excluding the price from the conjoint analysis and estimate the reservation price with an additional interview scene which also allows for non-purchases.

3 Reservation Price Estimation based on Economic Theory

Following Varian (2003, p. 63) a utility function for two products X and Γ can be formulated as

$$U(x,\gamma) = u_X(x) + u_\Gamma(\gamma). \tag{1}$$

Hereby x is the amount of product X, for which the reservation price of one specific individual is to be estimated, and γ denotes the amount of the so-called composite product Γ. Varian (2003, p. 21) defines the composite good as everything that the consumer might want to buy other than good X. By definition the amount of money not spent on good X is spent on good Γ. Note, that the composite good is arbitrarily divisible and also includes the possibility to save money for later consumption.

The reservation price for a good X is defined as "the price at which the consumer is just indifferent between consuming good X or not consuming it" (Varian (2003, pp.108-109)). Therefore, the reservation price p_X^* for one unit of product X is found, when the customer is indifferent between purchasing or not purchasing the product. Formally, indifference can be expressed by the following condition

$$U(1,\gamma) = U(0,\gamma') \qquad \text{where} \qquad \gamma' > \gamma. \tag{2}$$

On the left hand side of this equation the utility is given for an individual who consumes one unit of product X and consumes some amount of the composite good. On the right hand side of the equation the individual does not consume product X and therefore consumes a greater amount of the composite good denoted by γ'.

When consuming the goods X and Γ at the unit prices p_X and p_Γ each consumer is confronted with an individual budget constraint which can be defined as $m = p_X x + p_\Gamma \gamma$. Since the composite good is defined to be arbitrarily divisible, we can set the price for one unit of Γ to 1 (Varian (2003, p. 21)). For the consumption and non consumption of one unit of product X the following equations derived from the budget constraint hold

$$\gamma = m - p_X \tag{3}$$
$$\gamma' = m. \tag{4}$$

We only consider the case of buying one or zero units of X. For zero units no utility is derived from X ($u_X(0) = 0$). For the sake of formal simplicity let u_X denote the utility of consuming one unit of product X, that is $u_X := u_X(1)$. Using the utility function in equation 1 the condition for indifference in equation 2 can be rewritten as

$$u_X + u_\Gamma(\gamma) = u_\Gamma(\gamma'). \tag{5}$$

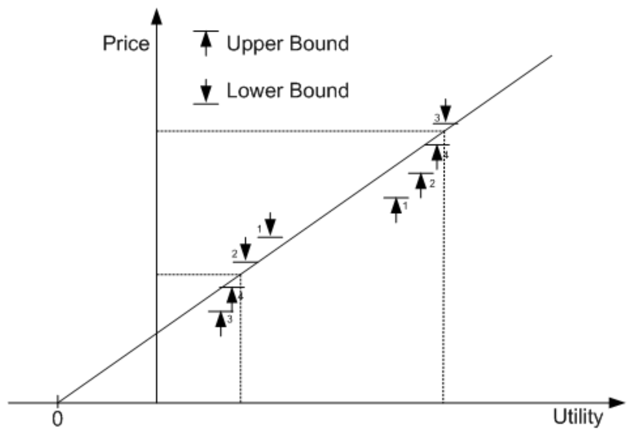

Fig. 1. Estimation of a high and a low reservation price point in the PE scene from observed upper- or a lower bounds of the price (denoted by the arrows).

When consuming the composite good, an individual will certainly always choose a combination that gives her the highest utility for her budget. Since the composite good is arbitrarily divisible and constructed from all possible goods (except good X), the consumer will face a large number of different combinations which equally have the same highest utility per price ratio k. Therefore, for $u_\Gamma(\gamma)$ a linear function with slope k and an intercept $u_\Gamma(0) = 0$ can be used (compare Jedidi and Zhang (2002)).

$$u_X + k \cdot \gamma = k \cdot \gamma' \tag{6}$$

Applying the budget constraint from equations 3 and 4 the following condition for the consumption of one unit of product X at the reservation price p_X^* can be formulated

$$u_X + k \cdot (m - p_X^*) = k \cdot m. \tag{7}$$

Applying some simple arithmetics to the equation m can be eliminated. Then, if the utility and the reservation price for one unit of product X is known, the slope k of the utility function of the composite product Γ can be calculated by

$$k = \frac{u_X}{p_X^*}. \tag{8}$$

Economically, the factor k represents the exchange rate between utility and money. With the factor k the reservation price for any product configuration for which the utility is known can be calculated. Note, that this calculation is based on ratio-scaled absolute utility but the conjoint analysis only produces interval-scaled utility-scores for products.

find-reservationprice-point$(u, p, \Delta u, \Delta p, \Delta p_{stop}, s_{max}, i)$:
$b^+ := (u^+, p^+) := \emptyset, b^- := (u^-, p^-) := \emptyset, j := 1$
while $b^+ = \emptyset$ or $b^- = \emptyset$ **do**
  if purchase(product$(u), p)$
    $b^- := (u, p)$
    $(u, p) := (u + \Delta u, p + j\Delta p)$
  else
    $b^+ := (u, p)$
    $(u, p) := (u - \Delta u, p - j\Delta p)$
  fi
  $j := j + i$
od
while $p^+ - p^- > \Delta p_{stop}$ and s_{max}-- > 0 **do**
  $(u, p) := (\frac{1}{2}(u^- + u^+), \frac{1}{2}(p^- + p^+))$
  if purchase(product$(u), p)$
    $b^- := (u, p)$
  else
    $b^+ := (u, p)$
  fi
od
return $(\frac{1}{2}(u^- + u^+), \frac{1}{2}(p^- + p^+))$

Fig. 2. Search algorithm for a reservation price point.

However, in the following we will show how to transform the interval-scaled utility-scores to ratio-scaled absolute utility while estimating the factor k. For this transformation we append the new *Price Estimation scene* (PE scene) at the end of the adaptive conjoint analysis. At this point all part-worth utilities are already estimated by the conjoint analysis and the utility-scores for all attribute combinations can be calculated. The PE scene is a choice-based scene where we offer the proband several times a different product at a dynamically set price and he or she has the option to accept the offer or leave it. With these questions we iteratively search for two reservation price points in the $utility \times price$ space. As shown in figure 1 with every question we find an upper or lower bound for price at a certain utility. Once we have found the reservation prices for two different products a straight line through the two points gives us an estimate for the factor k. At the same time we get an intercept with the utility axis which represents the conjoint analysis utility-score for the price 0 which by economic theory must correspond to an absolute utility of 0. Therefore, as shown in figure 1, we can assign an origin to the utility axis and utility is now ratio-scaled as necessary for reservation price estimation.

The algorithm for the estimation of the reservation price of one product combination is presented in figure 2. The function *product*(u) chooses the product configuration closest to a desired utility u from the list of all possible combinations. Function $purchase(product(u), p)$ asks whether the user would buy the product chosen by $product(u)$ at a given price p.

The first while loop in figure 2 starts with an initial guess (u, p). The algorithm tries to box the probands utility/price exchange ratio by locating an upper and a lower bound (b^{+}, b^{-}), i.e., a price point at which the proband would purchase for a given utility and one at which the proband would decline to purchase. In the second loop of the algorithm this interval is gradually narrowed by a bisection search. The bisection search terminates when the found interval, in which the reservation price lies, is narrowed to a predefined accuracy Δp_{stop}. To limit the maximal number of purchasing decisions a participant has to make, a second termination condition restricts the algorithm to a predefined maximal number of search steps s_{max}.

If only two reservation price points, (u_1, p_1) and (u_2, p_2), are used, the utility/price exchange ratio can be easily found by $k = (u_2 - u_1)/(p_2 - p_1)$. When $n > 2$ reservation price points (u_i, p_i) are used the utility/price exchange ratio can be found by least squares fitting.

The possibility that the procedure influences the respondent's behavior needs attention. To avoid this influence the respondent should be explicitly asked to view each offer independently. Furthermore, the respondent can be presented product combinations from the n reservation price estimations in randomized or alternating order (e.g. alternating high utility with low utility combinations), such that the influence is minimized.

4 Application of the Method

We implemented the PE scene in the modular framework of the Java Adaptive Conjoint tool (jAC version 1.1, Schmidt-Thieme (2004)) and incorporated it in a study designed for the NOKIA online-shop in the German market for mobile phones and accessories. In this shop customers are offered suitable telephone enhancements at discounted price on the purchase of a telephone. In terms of Pigou (1920) this strategy can be described as price discrimination of the third degree, because the shown telephone enhancements are only offered to a certain group of people at a lower price. The strategy can also be viewed as a mixed-bundling strategy as described by Adams and Yellen (1976). The telephone is offered together with enhancement at a discount, but the products can also be purchased individually without a discount. At the moment the marketing experts of the online-shop set the discounts for the telephone enhancements manually in view of the cost structure and sales information of the different products.

To enable the online-shop to optimize the pricing strategy we estimate the reservation prices of customers at the individual level. First, we use the adaptive conjoint analysis to estimate the part-worth utilities of all attribute levels excluding the price information. And then, we use the Price Estimation scene to estimate the reservation prices.

Utility	Reservation Price	Extra Charger	Car Accessory	Headset	Leather Case
17,64	171,46 EUR	ACP-12E	LCH-12	HDW-2	CNT-327
17,26	168,59 EUR	DCV-14	LCH-12	HDW-2	CNT-327
17,05	167,01 EUR	ACP-12E	-	HDW-2	CNT-327
16,67	164,14 EUR	DCV-14	-	HDW-2	CNT-327
16,60	163,63 EUR	ACP-12E	MBC-15S	HDW-2	CNT-327
16,22	160,77 EUR	DCV-14	MBC-15S	HDW-2	CNT-327
15,99	159,05 EUR	ACP-12E	LCH-12	HS-3	CNT-327
15,97	158,93 EUR	ACP-12E	LCH-12	HDW-2	-
15,61	156,19 EUR	DCV-14	LCH-12	HS-3	CNT-327
15,59	156,06 EUR	DCV-14	LCH-12	HDW-2	-
15,43	154,87 EUR	-	LCH-12	HDW-2	CNT-327
15,40	154,60 EUR	ACP-12E	-	HS-3	CNT-327

Table 1. Estimated reservation prices for a sample proband.

A large-sample online study will be carried out with the newsletter recipients of the NOKIA online-shop later this year. Here we only show how the procedure works by presenting results from a single sample participant. We searched for two reservation price points (with utilities around the 0.25 and 0.75 quantiles). Utility increments Δu were chosen to allow 20 steps in the search procedure. Δp_{stop} was set to 2,- EUR. Initial guesses for prices, price increments, and increase in step length were set by domain experts. Table 1 contains a subset of the results for the sample proband. The exchange rate between utility (measured by the conjoint analysis) and reservation price was estimated to $utility = 0.13 \cdot price - 5.22$ (rounded values). The stimuli of the conjoint analysis consisted of a fixed telephone and contract with different additionally bundled components.

¿From a single interview we can estimate reservation prices for all product combinations at the individual level. However, we can also aggregate the data to estimate reservation prices at market-level. To avoid the problem of preference heterogeneity we can segment the customers by self-selection, i.e., the preference for a certain phone type (business, fun, etc.), demographic variables, or characteristics of the self-explicated task of the adaptive conjoint analysis (Moore et al. (1998)). For these, more homogeneous groups distributions of reservation prices can be estimated. By applying an appropriate choice rule market reaction at different prices can be predicted.

5 Conclusion and Further Research

The approach presented in this paper addresses shortcomings of traditional pricing studies with conjoint analysis that arise from including price as an attribute in the study. We exclude price from the conjoint analysis and estimate it in an additional interview scene. With this procedure the *number-of-levels effect* and the *range* effect do not occur for price. Furthermore, by the use of a no-purchase option we can also measure the reservation price as defined in economic theory.

The new approach needs to be tested in a real setting which will be done in a large-sample reservation price survey together with the NOKIA online-shop. Further research is also necessary to compare this approach to traditional pricing studies and other techniques of reservation price estimation as described by Sattler and Nitschke (2003).

Finally, it has to be noted that the presented approach is not bound to conjoint analysis. Any estimation method that delivers preference information for products and product combinations relatively scaled at the individual level can be combined with our new estimation scene.

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