Constructing Willingness to Pay for Product Attributes in the Probability Space

Paul F. Burke, School of Marketing, University of Technology, Sydney
paul.burke@uts.edu.au

Presenting Author: Paul F. Burke

Abstract

This paper outlines several approaches used to construct measures of willingness to pay (WTP) for product attributes. We argue that measures based on consumer nomination require an unrealistic task and/or inconsistent with most revealed preference data. Compensating Variation, based on MNL model output, uses estimates of parameters constructed from a more familiar task, product choice. Compensating Variation (CV), however, is dependent on the base market from which comparisons are made. It also presents anomalies in relation to expected values of consumer WTP for changes in price.

In this paper, a WTP measure is constructed by equating changes in probability in product attributes with changes in price. As a result, WTP for each product attribute can be constructed from choice model estimates, but address the independence of base problem and allow for many alternatives and attributes. We demonstrate its practicality in expressing changes in products on various features in monetary terms. In turn, it provides an easily communicated and managerially informative measure for determining price, especially in markets where consumer evaluation of features is not well understood (e.g., new products).

Introduction

Often in pricing decisions, it is useful to know the relative value consumers place on various product attributes. For example, retailers of DVD recorders may find it useful to know the monetary value consumers place on new product features, such as simultaneous record and play. Manufacturers may modify an existing product line (e.g., new flavour). A service operator may decrease the number of offerings in their standard package. Consumers may only be willing to accept the altered offerings if they are able to pay a lesser amount. The prevailing objective that arises in these and similar situations is to determine consumer's willingness to pay (WTP) for changes in specific product features. If one is able to determine consumer WTP, then one can accordingly adjust prices and/or support through price promotions (e.g., rebates), when strategic or forced alteration of product offerings occur.

Several measures of WTP have been offered in the marketing literature. In this paper, we briefly review measures related to direct nomination of WTP amounts usually elicited in experimental settings. Motivated by several issues related to self-nominated measures, we then show how data consistent with random utility theory (e.g., observed choices) can be useful in constructing alternative measures of WTP. We then review the compensating variation formulation and construct a new measure by equating changes in product attributes and price in terms of the probability space, discussing its implications for marketing practice.

Nominating Willingness to Pay

One way to determine WTP is to ask consumers directly (e.g., Hsee, 1996). Arrow *et al* suggest direct elicitation techniques to obtain WTP are prone to bias (1993). Nomination of prices by consumers is problematic because they seldom perform this task. It is sellers who often nominate prices, determined from a number of pricing methods (e.g., mark-up on cost; demand forecasting). Consumers simply choose whether they are willing to pay the determined price. In some markets (e.g., auctions) there is some negotiation of price but often the seller nominates a price to begin the bargaining process. In other settings, a priori determined prices are an important aid in consumer's evaluation of products differentiated by novel and/or meaningless features (e.g., Carpenter, Glazer and Nakamoto, 1994).

Nominated WTP is problematic in non-experimental markets, where consumers do not readily report this information directly. We might observe, however, revealed preference data, detailing the inventory of products bought at various prices (e.g., scanner data). Through their consumption behaviour, consumers do suggest what set of prices are reasonable and what they are willing to pay. This behaviour can be captured using the axioms of random utility theory (Thurstone, 1927) and its extensions to choice modelling (McFadden, 1974; Ben-Akiva and Lerman, 1985). Choice models present an alternative but indirect approach to measuring the monetary value of product features. Such models can be estimated from a variety of data sources, including stated preference measures (e.g., choice-based conjoint).

Using Choice Model Estimates to Construct Willingness to Pay

One approach for relating choice model output in the form of preference measures to measures of WTP is compensating variation (Adamowicz 1997; Louviere, Swait and Hensher, 2000, p.340). Louviere, Hensher and Swait argue that Compensating Variation (CV) is potentially superior to other measures of WTP in cases in which there are multiple alternatives (2000). CV is written as a function of the variation in expected value of alternatives from a base condition to a proposed condition, and expressed as:

$$CV = \frac{-1}{\mu}\left[\ln\sum_{i=1}^{J}\exp(V_i^0) - \ln\sum_{i=1}^{J}\exp(V_i^1)\right]$$

where μ refers to the 'marginal utility of money', captured by the price coefficient in the multinomial logit model, and V_i is the systematic utility of option 'i'.

In practice, however, CV is problematic because it is dependent on the existing performance of products (i.e., base market used for comparison). To illustrate, consider a choice-based conjoint experiment conducted by Burke (2004), revealing estimates of consumer preferences for features of DVD recorders (Table 1). The aim of this experiment was to assess the monetary value of features for which great uncertainty exists.

Table 1: MNL Estimates for choice of DVD Recorders

Attribute	β	Se_β	Attribute Levels	
Intercept	-.4075	.0657	X=-1	X=+1
Price (PRC)	-.4829	.0420	$900	$1100
Ease of Use (EOU)	.2982	.0411	2 stars	4 stars
Simultaneous Record and Play (SRP)	.3947	.0417	Not Available (N/A)	Available
Hard Drive Capacity (HDC)	.2546	.0410	12 hours	25 hours

The estimates allow one to predict mean utility, V_i, for various offerings of DVD recorders, as shown in Table 2. To calculate the monetary value consumers place on simultaneous record and play (SRP), consider a CV calculation, comparing a market where one product changes from not having to having the feature. Beginning with a market containing products 'A', 'C' and a 'none' option (Case I, Table 3), and comparing to a market such that product 'A' now has the SRP feature, the CV calculation suggests consumers WTP for the SRP feature is $48.62. This amount contradicts the WTP of $91.20 using CV if one examined a different base market in which product 'B' is initially considered and altered (Case II, Table 3).

Table 2: Offerings of DVD Recorders

Product	A	A_{new}	B	B_{new}	P	C	Option N
PRC	**$900**	$900	$900	**$900**	**$1100**	$1100	**I would not**
EOU	2 stars	2 stars	4 stars	4 stars	2 stars	4 stars	**buy any of the**
SRP	**N/A**	**Available**	**N/A**	**Available**	N/A	N/A	**presented**
HDC	12 hours	12 hours	25 hours	25 hours	12 hours	25 hours	**alternatives**
Vi	*-.8721*	*-.0827*	*.2335*	*1.0229*	*-1.8379*	*-.7323*	*0*

Table 3: Comparison of Compensating Variation

Case	Description of Change	Base Market	New Market	CV
I	Target Attribute (base 1)	A,C,None	A_{new},C,None	$48.62
II	Target Attribute (base 2)	B,C,None	B_{new},C,None	$91.20
III	Price (by $200)	A,C,None	P,C,None	-$30.36

The contradicting calculation of WTP using CV reduces the theoretical and practical value of this measure. For example, Auger *et al* (2003) report CV based WTP measures of ethical attributes (e.g., use of child labour) relative to other attributes (e.g., price, brand) within two product categories (shoes and soaps). For simplicity, the authors assume a comparative base product where "all the value base product features were available …" (Auger *et al*, 2003, p. 302). The relative monetary value of ethical attributes will be different if alternate comparative bases are used (e.g., all product features at non-base level of performance).

Anomalies also arise when one measures the CV for changes in price. One expects this measure should reflect equivalent changes in price. If product A's price increases from $900 to $1100, and no other changes in the market occur, one should expect that consumers would be willing to be compensated by an amount of $200, if buying product A. The CV measure does not always reflect this expectation (Case III, Table 3).

In summary, there is a need to determine a measure of WTP that:

(a) Incorporates measures obtained from what consumers readily do, such as choosing between various product offerings;
(b) Is independent of a base market from which comparisons are made;
(c) Can cater for situations in which choice is made from many alternatives; and,
(d) Reflects changes in price as equivalent changes in WTP.

We now construct such a measure by examining WTP in the probability space rather than marginal or expected utility space. We identify a price that will equate predicted changes in probability arising when product offerings alter. WTP for any product attribute can then be composed from choice model estimates when a measure of price (e.g., price in dollars; interest rate) describes available options.

Willingness to Pay Constructed in the Probability Space

Define a market in which option 'j' is available at a base level of price and base level of a target attribute, τ. Let the probability that this option be chosen be denoted by P_j^{00}. The first and second superscript denote the performance of option 'j' on the target attribute and its price respectively. The values of the superscript, zero and one, indicate whether performance on such attributes is unchanged and changed, respectively.

Imagine that a manufacturer changes the performance of option 'j' on a target attribute,τ, but its performance on all other attributes is stable. Assume that all other options in the market are unchanged. The probability that option 'j' is chosen in this case is P_j^{10}. The change in probability that occurs from one market to the next is $P_j^{\Delta\tau}$, where $P_j^{\Delta\tau} = P_j^{00} - P_j^{10}$. In contrast, imagine that the manufacturer changes only the price of option 'j', leaving its performance on all other attributes constant. This change will alter choice probabilities if no monetary compensation is provided, and depend on consumer price sensitivity. This change in probability of purchasing option ‘j’ is written as $P_j^{\Delta p}$, where $P_j^{\Delta p} = P_j^{00} - P_j^{01}$.

Strategically, a manufacturer of product ‘j’ could choose to change its price or change its performance on the target attribute. Both strategies will bring about a change in the probability that consumer’s choose option ‘j’. Equating these changes in probability allows WTP to be determined. Specifically, we can solve the equation $P_j^{\Delta \tau} = P_j^{\Delta p}$ to find an expression for the price level, x_{jp}^{01}. This price results in an identical change in probability to that observed if product ‘j’ had only changed its performance on the target attribute.

A technical appendix provides a specific mathematical development based on this formulation, resulting in a measure of WTP. Consumer willingness to pay (WTP) for a change in a product on the set of attributes, τ, can be expressed as:

$$WTP_{\tau}^{ps} = \left(\frac{\beta_{\tau}}{\beta_{p}} \right) \Delta x_{j\tau}$$

where, β_τ and β_p refer to preference estimates of the MNL model, reflecting sensitivity of consumers to changes in product performance on the target attribute and price respectively. $\Delta x_{j\tau}$ is the change in performance for which WTP measure refers, and will be one if $x_{j\tau}$ is effects coded or two if dummy coded. The WTP measure depends on the manner in which price is denoted in the model (e.g., treated as a categorical variable).

Returning to our illustrative example in the DVD recorder market, we can calculate the WTP for each attribute. Since effects codes are employed, $\Delta x_{j\tau}$ is always two. The WTP for having the simultaneous record and play feature relative to not having the feature is $163.47. This change is valued higher than changes in other attributes (see Table 4).

Table 4: WTP_τ^{ps} Estimates for Attributes of DVD Recorders

Attribute	β	Change in Performance	WTP_τ^{ps}
Price (PRC)	-.4829	$900 to $1100	-$200.00
Ease of Use (EOU)	.2982	2 stars to 4 stars	$123.50
Simultaneous Record and Play (SRP)	.3947	Not Available (N/A) to Available	$163.47
Hard Drive Capacity (HDC)	.2546	12 hours to 25 hours	$105.45

Advantages and Implications of WTP_τ^{ps}

WTP_τ^{ps} is obtainable from data based on what consumers readily do in real markets; that is, our inputs to the measure come from choice model estimates. Such estimates are also readily available from stated preference techniques (e.g., choice-based conjoint experiments). The measure can accommodate (and unaffected by) the number of product alternatives and attributes. The measure depends only on absolute changes in product features rather than changes made in relation to some base. In other words, our conclusions about consumers WTP for a particular feature do not change as the basis for which our comparison is made.

It is not well understood that the parameter estimates, β_τ and β_p, are confounded by the scale parameter of the random component (Louviere, 2001). The WTP measure constructed in the probability space takes the ratio of the two coefficient estimates. In turn, this removes the impact on scale on our measure of WTP. This is advantageous in cases where between group comparisons are made in relation to valuation of product features.

Our previous measure of WTP based on CV when the price of product ‘A’ changed from $900 to $1100, was a rebate of $30. This measure inaccurately reflects changes in price as equivalent changes in WTP. In contrast, WTP constructed in the probability space calculates consumer WTP for a $200 price increase as a $200 rebate.

From a theoretical and practical viewpoint, the formulation is advantageous because it allows a measure of WTP for each attribute. In turn, pricing decisions can be readily made. For example, new product development managers can readily convert the valuation of new product features into monetary terms using choice model estimates. This is advantageous from a strategic pricing decision, revenue forecasting and/or communication perspective.

References

Adamowicz, W., Swait, J., Boxall, P. Louviere, J. and Williams, M., 1997. Perceptions versus objective measures of environmental quality in combined and revealed states preference models of environmental valuation. Journal of Environmental Economics and Management. 32, 65-84.

Arrow, K., Solow, R., Portney, P., Leaner, E., Radner, R., and Schuman, H. 1993. Report of the NOAA Panel on Contingent Valuation. Federal Register. 58, 4601-4614.

Auger, P., Burke, P., Devinney, T.M., and Louviere, J.J., 2003. What will consumers pay for social product features?. Journal of Business Ethics. 42(3), 281-304.

Ben-Akiva, M.E., and Lerman, S., 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. Cambridge, Mass: MIT Press.

Burke, P.F., 2004. The Impact of Contextual Information on Evaluation of Products Differentiated by Fuzzy Features. Unpublished working paper. Sydney: Australian Graduate School of Management.

Carpenter, G.S., Glazer, R., and Nakamoto, K., 1994. Meaningful Brands from Meaningless Differentiation: The Dependence on Irrelevant Attributes. Journal of Marketing Research. 31(3), 339-350.

Hsee, C.K., 1996. The evaluability hypothesis: An explanation for preference reversals between joint and separate evaluations of alternatives. Organizational Behavior and Human Decision Processes. 67(3), 247-257.

Louviere, J.J., Hensher, D.A., and Swait, J.D., 2000. Stated Choice Methods. Cambridge: University Press.

Louviere, J.J., 2001. What If Consumer Experiments Impact Variances as well as Means? Response Variability as a Behavioral Phenomenon. Journal of Consumer Research. 28(4), 506-511.

McFadden, D., 1974. Conditional Logit Analysis of Qualitative Choice Behavior. In Zarembka, P. (Ed.). Frontiers in Econometrics. New York: Academic Press, 105-142.

Thurstone, L., 1927. A law of comparative judgement. Psychological Review. 34, 273-286.

Technical Appendix

The equivalent change in price required to equate the change in probability occurring when an option changes its performance on a target attribute, τ, is given by rearranging the equation:

$$P_j^{\Delta\tau} = P_j^{00} - P_j^{01} = P_j^{00} - P_j^{10} = P_j^{\Delta p}$$

where the first and second superscripts denote the performance of option 'j' on the target attribute and price respectively. The values of the superscript zero and one indicate whether performance on such attributes is unchanged and changed, respectively.

Subtracting P_j^{00} from both sides, and multiplying by -1:

$$P_j^{01} = P_j^{10}$$

This can be rewritten using McFadden's (1974) multinomial logit formulation:

$$\frac{\exp(V_j^{01})}{\sum_{m=1}^{M}\exp(V_m^{01})} = \frac{\exp(V_j^{10})}{\sum_{m=1}^{M}\exp(V_m^{10})}$$

Where M is the number of choice alternatives. The summation expression of the utility of all alternatives in the market, expressed in the denominator, can be rewritten to discriminate between the target alternative being changed (i.e., option 'j') and all other (M-1) options:

$$\frac{\exp(V_j^{01})}{\exp(V_j^{01}) + \sum_{m=1}^{M-1}\exp(V_m^{01})} = \frac{\exp(V_j^{10})}{\exp(V_j^{10}) + \sum_{m=1}^{M-1}\exp(V_m^{10})}$$

Cross-multiplying and expanding:

$$\exp(V_j^{01})\cdot\exp(V_j^{10}) + \exp(V_j^{01})\cdot\sum_{m=1}^{M-1}\exp(V_m^{10}) = \exp(V_j^{10})\cdot\exp(V_j^{01}) + \exp(V_j^{10})\cdot\sum_{m=1}^{M-1}\exp(V_m^{01})$$

Subtracting $\exp(V_j^{01})\cdot\exp(V_j^{10})$ from both sides:

$$\exp(V_j^{01})\cdot\sum_{m=1}^{M-1}\exp(V_m^{10}) = \exp(V_j^{10})\cdot\sum_{m=1}^{M-1}\exp(V_m^{01})$$

Since the set of alternatives are fixed, $\sum_{m=1}^{M-1}\exp(V_m^{10}) = \sum_{m=1}^{M-1}\exp(V_m^{01})$, and, hence:

$$\exp(V_j^{01}) = \exp(V_j^{10})$$

Taking the natural logarithm of both sides:

$$V_j^{01} = V_j^{10}$$

Let η refer to those attributes of 'j' which remain unchanged. Decomposing the systematic expression to discriminate between the various attributes of interest can be written:

$$\beta_\eta x_{j\eta}^{01} + \beta_\tau x_{j\tau}^{01} + \beta_p x_{jp}^{01} = \beta_\eta x_{j\eta}^{10} + \beta_\tau x_{j\tau}^{10} + \beta_p x_{jp}^{10}$$

The performance on 'j' on all non-target attributes is fixed, and therefore $x_{j\eta}^{01} = x_{j\eta}^{10} = x_{j\eta}$.

Subtracting $\left(\beta_\eta x_{j\eta} + \beta_p x_{jp}^{01}\right)$ from both sides and dividing by β_p gives:

$$x_{jp}^{01} = \frac{\beta_\tau x_{j\tau}^{10} + \beta_p x_{jp}^{10} - \beta_\tau x_{j\tau}^{01}}{\beta_p} = \left(\frac{\beta_\tau}{\beta_p}\right)\left(x_{j\tau}^{10} - x_{j\tau}^{01}\right) + x_{jp}^{10}$$

This is the price of the product which will result in the equivalent probability of option 'j' being chosen if the target attribute τ had been changed rather than price. Defining willingness to pay, constructed in the probability space, WTP_τ^{ps}, to be the change in price required to match a probabilistic change from changing option 'j' on the target attribute, τ, is then:

$$WTP_\tau^{ps} = x_{jp}^{01} - x_{jp}^{10} = \left(\frac{\beta_\tau}{\beta_p}\right)\left(x_{j\tau}^{10} - x_{j\tau}^{01}\right) = \left(\frac{\beta_\tau}{\beta_p}\right)\Delta x_{j\tau}$$