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A Method for Handling a Large Number of Attributes in Full Profile Trade-Off Studies

Often product developers need to evaluate a large number of product features, measure some interaction terms, e.g., brand and price or a multidimensional pricing structure, and express the product concepts in some realistic, full-profile format. The approach outlined above offers a cost and time efficient solution to those requirements.

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Abstract

Full profile conjoint- or choice-based trade-off studies have traditionally been limited to six attributes. Full profile studies allow for the estimation of interaction terms and generally present more realistic choices to the respondent than partial profile or self-explicated approaches. However, clients often want to test a long list of potential product features that may or may not be included in the final product, depending on the results from research. Additionally, they may be interested in complex pricing issues that require some interaction effect estimation or wish to test certain attributes such as brand and price in a "full profile' format. Being limited to six attributes renders traditional full profile trade-off analysis useless in this situation.

The method described here has been developed and successfully applied numerous times and offers several advantages over traditional full profile conjoint and choice methods:

- A large number of product features (50 or more) can be included in the model
- Selected first order interactions can be estimated at both the disaggregate and aggregate levels
- Since product combinations are specified, via traditional experimental design, before the interview takes place, physical exhibits can be easily incorporated into the interview

Introduction

Trade-off analysis is a family of methods by which respondents' utilities for various product features (usually including price) are measured. In some cases, the utilities are measured indirectly. In this case, respondents are asked to consider alternatives and state a likelihood of purchase or preference for each alternative. As the respondent continues to make choices, a pattern begins to emerge which, through complex multiple regression (and other) techniques, can be broken down and analyzed as to the individual features that contribute most to the purchase likelihood or preference. The importance or influence contributed by the component parts, i.e., product features, are measured in relative units called "utils" or "utility weights."

In other cases, respondents are asked to tell the interviewer directly how important various product features are to them. For example, they might be asked to rate on a scale of 1 to 100 various product features, where 1 means not at all important to their purchase decision and 100 means extremely important to their purchase decision.

Trade-off analyses produce several types of information. First, they tell us what features (and levels of features) are most valued by customers. Second, they allow us to model how likely people will be to purchase various configurations of products, the share of revenue these products will most likely receive and what role price plays in the assessment of acceptability.

There are four main types of trade-off:

- Conjoint
- Discrete Choice
- Self-explicated
- Hybrid

Within both conjoint and discrete choice methods, there exists a further subdivision into full profile and partial profile approaches. Full profile methods use one level from each attribute in the study when defining a product configuration for respondents to rate or rank. Partial profile methods allow the researcher to design product configurations based on a subset of all the attributes included in the study. Partial profile methods generally accommodate more attributes than full profile methods.

Before briefly describing each of the four general approaches to trade-off analysis, two additional concepts need to be introduced:

- Bridging
- Cognitive attributes

Bridging

Occasionally, even with the most efficient fractional factorial design, we still end up with more products than can be practically accommodated. One possible solution to that problem is bridging[1]. Bridging allows the attributes to be divided into two or more sets (with some attributes common to all sets). Each set of attributes is treated like its own trade-off study. A fractional factorial design is created for each set of attributes. Respondents are asked to rate or rank two smaller sets of products rather than one large set. The utilities are calculated for each trade-off exercise independently and bridged together to create one final set of utilities.

Cognitive and Non-cognitive Attributes

Critical to the selection of an appropriate trade-off technique is the issue of which type of attributes, cognitive or non-cognitive, are being represented in the trade-off exercise. Cognitive attributes are attributes that are based on rational, conscious, generally verbal decision making. Such easily quantifiable factors as clock speed, interest rate or size are typically cognitive. Non-cognitive attributes are attributes that are less explicit, more emotional or even less conscious such as brand, price, industrial design, graphic designs en toto or even graphic design elements, such as

[1] Pierre François, Douglas L. MacLachlan and Anja Jacobs, Bridging Designs for Conjoint Analysis: The Issue of Attribute Importance, Leuven, Belgium, 1991-2. An unpublished paper.

color, typeface or geometric shapes. One might argue that the selection of a life insurance policy, a computer or a water heater are all cognitive decisions and that the selection of a beer, a skin cream or a pair of pants are all non-cognitive. One might also argue that all decisions made by humans are at least partially non-cognitive. This issue, as it relates to trade-off analysis, deservers further investigation.

However, trade-off techniques that employ direct questions (self-explicated and most hybrid techniques) all necessarily assume that the attributes being modeled are all cognitive, because at least some of the product features are being rated in a way that requires both awareness and honesty from the respondent. That is, the respondent must be aware of the degree to which a product feature affects his or her purchase decision and also be willing to admit to that degree of effect.

Additionally, any data collection methods that rely on verbal or written descriptions of product features all assume that the attributes being modeled are cognitive, because the process of understanding a verbal or written description is itself a cognitive behavior.

Non-cognitive trade-off models, that is, models involving non-cognitive attributes, should be based on an indirect trade-off technique (conjoint or discrete choice) and data collection that relies on complete product experience rather than language describing single attributes alone to communicate the product choices. That is, for trade-off models involving non-cognitive attributes, use full-profile techniques. For example, if you are modeling the pant purchasing process, show respondents a variety of pants that they can see and touch. A consumer may respond to the phrase "light blue pants" very differently than he or she would to a particular pair of light blue pants.

Conjoint Analysis

Conjoint analysis is the original trade-off approach and uses linear models. There is metric conjoint, where respondents monadically rate various product configurations, and non-metric conjoint, where respondents rank a set of product configurations. There are also full-profile conjoint, partial-profile conjoint and pairwise conjoint. Full-profile conjoint uses all product features in every product configuration. Partial profile conjoint uses a smaller subset of available product features in the product configurations. Pairwise conjoint requires the respondent to rate their preference for one product over another in a paired comparison.

Conjoint models are simply regression models which are constructed for each individual respondent. Typically, each respondent rates or ranks 10 to 20 product configurations. Each product configuration contains different levels of the product attributes being tested. If the product levels are varied appropriately (the role of experimental design), a regression model can be estimated for each individual, using the product ratings as cases. The coefficients from the model, or scaled variants of the coefficients, are the utilities or utils.

A conjoint approach should be used if a limited number of attributes needs to be tested and utilities need to be estimated for individual respondents, e.g., for conjoint-based segmentation.

Discrete Choice

Discrete choice differs from conjoint in that respondents are shown a set of products from which they pick the one they most want to buy or none if they are not interested in any of the choices shown (rather than rate or rank choices). Respondents are shown several sets of choices sequentially. For each choice set, they are asked to pick one or none. This is in contrast to most forms of conjoint where respondents are not allowed to choose none of the product options. The discrete choice procedure has the advantage of being more like the actual purchase decision process than do any of the data collection methods used in most conjoint studies.

Also, in conjoint methods, the mathematical models constructed to simulate market behavior are based on linear regression models. In discrete choice, the basis is the multinomial logit model[2], which is non-linear. Another analytical difference is that, in conjoint procedures, the utility weights are estimated for each respondent individually. Although individual level utility weights can be estimated for discrete choice designs, those weights are not estimated directly but by drawing information from other similar individuals.

Discrete choice should be used if the primary objective of the study is to estimate market share or price sensitivity and a limited number of attributes needs to be tested.

Self-Explicated Scaling

Conjoint and discrete choice both determine respondents utilities indirectly. Self-explicated approaches determine respondents' utilities directly. With self-explicated scaling, respondents are asked directly how important all levels of all attributes are to their purchase interest. Despite its conceptual simplicity, self-explicated models have been shown, at least in some cases, to be comparable to conjoint models[3].

Self-explicated conjoint analysis requires respondents to reveal their utilities directly. Accordingly, standard questionnaire methods can be used to collect the information.

Self-explicated approaches are useful when there are a large number of attributes and the decision process being modeled is cognitive.

Hybrid Models

Hybrid models are models that use a combination of the above techniques. The most widely used hybrid model is ACA, Adaptive Conjoint Analysis[4].

Adaptive Conjoint Analysis

In this procedure, a computer program prompts the interviewer with questions. The procedure is as follows:

Respondents are first walked through a battery of feature-importance ratings and rankings; second, through a series of pairwise trade-offs of different product configurations. The product configurations shown to any one respondent may not include all of the attributes being tested.

The configurations to be paired are based on the answers to the importance questions and rankings asked in the beginning of the interview. Items that are considered of little importance show up in the comparisons less often. Items that are considered of greater importance show up in the comparisons more often.

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2 R. Duncan Luce, *Individual Choice Behavior: A Theoretical Analysis,* New York: John Wiley, 1959. Richard R. Batsell and Abba M. Krieger, *Least-Squares Parameter Estimation For Luce-Based Choice Models,* June, 1979.

3 V. Srinivasan, A Conjunctive-Compensatory Approach To The Self-Explication of Multiattributed Preferences, Decision Sciences, 1988, vol. 19.

4 ACA is a product of Sawtooth Software, Inc., Sequim, WA. Sawtooth Software offers a broad range of trade-off and other data analysis software products.

For each pair of products being tested, the respondent is to indicate which product they prefer and the degree to which they prefer it.

The software continues prompting with pairwise comparisons of product configurations until enough data has been collected to estimate conjoint utilities for each level of each feature. Since the procedure is adaptive, only a fraction of the total number of possible product combinations are tested.

ACA is an approach that is appropriate for building preference models of cognitive behavior with large numbers of attributes. It may not be as useful when price sensitivity, non-cognitive purchase decisions or interaction terms are to be modeled.

A New Approach

Full profile conjoint- or choice-based trade-off studies have traditionally been limited to no more than six attributes[5]. Partial profile, self-explicated scaling or hybrid methods have been used when a large number of attributes need to be included in the model. Full profile studies allow for the estimation of interaction terms and generally present more realistic choices to the respondent than partial profile or self-explicated approaches.

However, clients often want to test a long list of potential product features that may or may not be included in the final product, depending on the results from research. These product features are often cognitive in nature. Additionally, they may be interested in complex pricing issues that require some interaction effect estimation or wish to test certain attributes such as brand and price in a “full profile’ format. Being limited to six attributes renders traditional full profile trade-off analysis useless in these situations.

A method has been developed and successfully applied numerous times which offers several advantages over both traditional full profile and partial profile conjoint and choice methods:

- A large number of product features (50 or more) can be included in the model
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The basic steps of the procedure are as follows:

- Questionnaire content:
    - Product feature importance ratings: In this section, respondents are asked to rate each of a list of product features for purchase interest. Several of the features included in the importance ratings will be included in the conjoint exercise as well.
    - Full profile trade-off exercise: The respondents then participate in a "full-profile" trade-off exercise. The full-profile products consist of six attributes, at least one of which is included in the importance ratings above.

5 It is commonly believed that respondents have difficulty comprehending more than six attributes in a product configuration (see CBC User Manual, version 2.0, pages 3-5 and 3-6, Sawtooth Software, Inc., Sequim, WA).

- Analysis
  - Using any of a variety of available conjoint or choice[6] software, utility weights for each feature in the trade-off exercise (data step 2) can be estimated for each respondent.
  - Utilities are then bridged from data step 1 with data step 2. On a per respondent basis, a scalar can be estimated using the common features in data step 1 and data step 2. Numerous algorithms for bridging exist. We typically use the Symbridge[7] method.
  - The scalar reduces the feature scores in data step 1 to a scale equivalent with data step 2 utility weights.
  - On a per respondent basis, this scalar is multiplied by each score in data step 1 to achieve utility weights comparable to data step 2 utility weights.
  - Data step 1 and data step 2 utility weights are then merged to create one set of bridged utility weights (with the utility values from data step 2 used for the attributes common to both steps).
  - These merged utility weights define the conjoint or choice model from which all subsequent simulations will be based.

All self-explicated features are necessarily additive[8]. This can yield misleading results if too many features are included in the model. A correction for excessive feature bias has been developed based on the assumption that, when selecting products, respondents consider no more than six features at a time[9].

The correction procedure is as follows. When calculating total product utility for each individual:

- Identify the six attributes with largest relative importance
- Include only the selected levels from those six attributes when calculating total product utility for that individual
- Include all individuals' total product utilities in the simulator as normally done

An Example

For our 2000 ART Forum presentation, we conducted a web-based survey on network computers.

The sample was a purchased opt-in email list of American adults. 1,000 email invitations to participate in the web survey were mailed. 429 interviews were completed over the time period May 6-11, 2000.

Questionnaire content included:

- Product description

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6 To my knowledge, the only commercially available software which allows for individual level utility estimates for discrete choice models is offered by Sawtooth Software, Inc., Sequim, WA, through either their HB or ICE modules.

7 Pierre François, Douglas L. MacLachlan and Anja Jacobs, Bridging Designs for Conjoint Analysis: The Issue of Attribute Importance, Leuven, Belgium, 1991-2. An unpublished paper.

8 Denis Kilroy and Peter Williams, Calibrating Price in ACA: The ACA Price Effect and How to Manage It, 2000 Sawtooth Software Conference Proceedings, March 2000.

9 Paul Richard "Dick" McCullough, Comment on Kilroy and Williams, 2000 Sawtooth Software Conference Proceedings, March 2000.

- Holdout card
- Self-explicated scaling of 7 attributes
- 10 Trade-Off pairwise ratings based on 4 attributes
- 3 Hold Outs w/ trade-off attributes only
- 3 Hold Outs w/ all attributes (last hold-out duplicated at front of survey)
- Respondent demos

There were nine attributes in total:

- Price
    - Free with 2 year ISP commitment
    - $99
    - $199
- Clock speed
    - 200 Megahertz
    - 300 Megahertz
- Internal memory
    - 32 Megabytes
    - 64 Megabytes
- Ethernet port
    - Included
    - Not included
- Printer port
    - Included
    - Not included
- USP port
    - Included
    - Not included
- Wireless keyboard
    - Included
    - Not included
- 24/7 telephone tech support
    - Included
    - Not included
- 30 day unconditional money back guarantee
    - Included
    - Not included

The attributes clock speed, Ethernet port, printer port, USB port, wireless keyboard, 24/7 tech support and 30 day guarantee were included in the self-explicated segment of the survey.

The attributes price, clock speed, memory and Ethernet port were included in the "full-profile" segment of the survey. Sawtooth's CVA software was used to design the full-profile conjoint exercise and to estimate conjoint utilities.

Note that the two attributes clock speed and Ethernet port were common to both the self-explicated scaling and the trade-off exercise so that the utilities from each section could be bridged together.

The self-explicated utilities were bridged with the conjoint utilities using the partworth bridging technique describe above. A four attribute model was constructed using only the conjoint utilities. A nine attribute model was constructed using the bridged utilities.

Additionally, the nine attribute model was amended with the top six correction to the excessive feature bias.

Three hold out cards were designed which contained the four attributes included in the "full-profile" segment and three hold out cards were designed which contained all nine attributes. One of the nine attribute hold out cards was repeated to measure study reliability.

The table below shows the hit rates and mean absolute error (MAE) for the four attribute model, the nine attribute model, the nine attribute model with top 6 correction and the test/retest hold out.

Table 1.

	Hit Rate	MAE
Test/retest	79%	0.03
4 attribute model	72%	0.033
9 attribute model	77%	0.034
9 attribute model with top 6 correction	76%	0.028

The above data show that the original 4 attribute model works very well. Its hit rate is very close to the maximum possible, that is, the 79% hit rate for test/retest. The nine attribute model, both with and without correction for excessive feature bias does slightly better than the four attribute model in terms of hit rate and virtually identically in terms of MAE.

Clearly, the hybrid form of self-explicated bridged with full-profile performs at least as well as full-profile alone and yet allows for a much larger number of attributes to be included.

The Top 6 correction factor did not improve either hit rates or MAE. This is most likely due to the fact that nine attributes are relatively small in number. It would be expected that the Top 6 correction factor would have a much greater impact on model performance if the number of attributes was much greater.

Commercial Examples

To illustrate the usefulness of the approach describe above, two commercial studies where this technique was successfully employed will be described.

Consumer Electronics

A client developing a new hi-tech consumer electronic product wanted to identify which attributes should be included in the final product. The client also wanted to measure price sensitivity and segment the marketplace. Client engineers had culled down the list of potential features into a three ring binder approximately five inches thick. Through numerous and lengthy internal discussions, the list of potential attributes was further reduced to 75. It was impossible for them to narrow their list further and there was not time for a qualitative stage of research.

The method described here was applied. Self-explicated ratings were collected for 75 potential product features. A full-profile trade-off study was conducted with six attributes, including two price attributes, brand and two features from the self-explicated section.

The data collection method was a telephone prerecruit to a central location. A personal, one-on-one interview was conducted that, on average, lasted 60 minutes. Many visual aids were used in the interview process to assist in rapid and accurate communication.

A clear pattern emerged regarding which features respondents preferred. Price sensitivity was measured and models estimated penetration rates across various market segments.

High-tech business-to-business

Another client wished to survey a very hard to reach group of high-tech professionals. They wished to measure feature importance, including price. Given cost constraints and the difficulty of reaching the desired population, telephone surveys were the only alternative considered. Although ACA can potentially underestimate price sensitivity, it was the preferred methodology due to its ease of implementation. However, the preferred field house did not use ACA. A different methodology was required.

By applying the above technique to a small number of attributes (six), a survey that was simple enough to conduct by telephone was created. The survey consisted of self-explicating five attributes and conducted conjoint ratings on 8 three attribute product configurations. The interview length was 10 minutes.

Summary

Often product developers need to evaluate a large number of product features, measure some interaction terms, e.g., brand and price or a multidimensional pricing structure, and express the product concepts in some realistic, full-profile format. The approach outlined above offers a cost and time efficient solution to those requirements.

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