Pay Now, Save Later: Using Conjoint Analysis to Estimate Consumers' Willingness to Pay for Energy Efficiency

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Abstract

What value do consumers place on energy efficiency? How can energy efficiency advocates quantify this value to estimate what price consumers are willing to pay for energy efficiency? This paper presents a methodology that enables analysts to estimate the value consumers place on energy efficiency, and estimate a dollar value for the willingness to pay for energy efficiency. This is done by reviewing a consumer analysis study conducted for the Department of Energy as part of the clothes washer standard rulemaking process.

The Department of Energy is considering a new energy efficiency standard for clothes washers. As part of this process, a consumer analysis study was completed using focus groups and conjoint analysis sessions to determine if the new standard would reduce the utility of clothes washers to consumers. Using clothes washer attributes chosen by focus groups, conjoint analysis sessions were held where respondents were asked to rank different hypothetical clothes washer choices. The advantage of the conjoint analysis is that equipment characteristics are presented together, requiring respondents to make tradeoffs between attributes as they would if they were actually purchasing a clothes washer. By examining how attribute rankings change with changes in the set of attributes being evaluated by the respondents, the value placed on the various equipment characteristics relative to each other is determined.

Introduction

Energy efficiency analysts are continually looking for better ways to empirically estimate the value consumers place on energy efficiency. One of the major analytic challenges is estimating the value of energy efficiency in relation to other attributes of a product attributes, such as purchase price, performance, size, etc. This is especially critical considering that energy prices have generally fallen over the last two decades. As a consequence, manufacturers are less inclined to improve the energy efficiency of their products without clear empirical evidence on what consumers are willing to pay for these energy efficiency improvements. To meet this challenge, an analysis tool is needed that enables the analyst to measure how the consumer will trade off various product attributes, much as a consumer does when he/she is making a decision to purchase Product A, B, C, or D in a retail store.

Conjoint analysis is an analytic tool that can help analysts meet this challenge. It requires respondents to make tradeoffs between attributes much as they would if they were actually purchasing a product. By measuring how the attribute rankings vary with changes in the set of attributes being evaluated by the respondents, the analyst can determine the value consumers place on each the product attributes included in the analysis. In short, conjoint analysis enables analysts to empirically estimate how much consumers are willing to pay to own an energy efficient product.

The Department of Energy (DOE) recently completed a conjoint analysis as part of the clothes washer efficiency standard rulemaking process. DOE is considering a new clothes washer energy efficiency standard. As part of the energy efficiency standard rulemaking process, DOE must determine "if any lessening of the utility or performance of the product is likely to result from the imposition of a standard" (42 USE Sec. 6295 (o)(2)(B)(I)(3)). To address this issue, consumer stated preference data were collected to determine the value consumers' place on clothes washer attributes that could be impacted by a new standard, such as door placement, price, efficiency level, and temperature settings.

The consumer analysis study utilized a two-step process. First, ten focus groups were held in five cities across the country to develop a list of clothes washer attributes valued by consumers. Second, data were collected from 435 respondents using a conjoint analysis survey to estimate which clothes washer attributes are valued most by consumers. The six attributes that were cited most often by the focus groups, and were likely to be affected by an efficiency standard, were included in the conjoint analysis survey. The conjoint analysis focussed on how respondents make these tradeoffs and allowed for the estimation of the relative values placed on the clothes washer features included in the conjoint survey. The ultimate goal of the analysis was to determine if consumer utility would be adversely affected by a proposed efficiency standard. This paper focuses on the two step methodology used in this effort, and highlights how these findings and this method can be used to estimate the value consumers place on energy efficiency.

Focus Groups

Focus groups were conducted in five cities; Washington, DC, San Francisco Bay Area, CA, Madison, WI, Miami, FL, Dallas, TX. These cities were selected so that five different regions of the country would be represented in the focus groups. Ten focus groups were conducted, two in each city, with a total of 90 focus group participants divided almost evenly across the ten sessions. Focus group participants were recruited randomly by phone to ensure a mix of demographic types. Respondents were required to be the person in the household that did the laundry and each respondent was paid a $50 incentive for participating in the focus group.

The primary purpose of the focus groups was to identify the most important clothes washer features. This was accomplished by the focus group moderator encouraging an open dialogue among focus group participants to obtain an unsolicited list of clothes washer attributes. Once the unaided list of attributes was obtained, the moderator suggested other attributes that were not volunteered initially for the group to discuss.[1] When the clothes washer attributes discussion was completed, the moderator asked the focus group participants to independently identify the ten attributes that would most significantly influence their selection of a new clothes washer, assuming they had already made the decision to purchase a new clothes washer. These responses were then totaled across all ten focus groups to determine the list of the most important clothes washer features to consumers.

Table 1 shows the top 12 characteristics mentioned from all of the focus groups as well as the percentage of respondents who listed that attribute. Price was mentioned most often as an important attribute for selecting a clothes washer, with 75 of 90 respondents mentioning price. This was followed by capacity, mentioned by 73 percent of respondents, and by energy and water costs, which was listed by 65 percent of the respondents. The ability to adjust the water to fit different wash load sizes, durability, and water temperature options were also mentioned by more than half of the respondents.

Table 1. Focus Group Attribute Ranking Results

Feature	Frequency Mentioned (Out of 90)
Price	83%
Capacity	81%
Energy & Water Costs	72%
Load Size Options	68%
Durability	60%
Water Temperature Options	60%
Door Placement	42%
Quiet Operation	40%
Wash Time	38%
Warranty	37%
Multiple Wash Cycle Options	33%
Horizontal/Vertical Axis	28%

Based on the focus group results, clothes washer price, energy and water savings, capacity, water temperature, door placement, and load size adjustment were selected as attributes to use in the conjoint analysis. Of this group, five of the six attributes will potentially be affected by an efficiency standard. In particular, door placement and its effect on consumer utility was of interest to DOE, based on concerns expressed by clothes washer manufacturers as well as several consumer group representatives.

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[1] The moderator relied upon on a list of possible attributes provided by clothes washer manufacturers to the Department of Energy.

Conjoint Analysis

Conjoint analysis is a stated preference survey technique that involves respondents sorting through and ranking cards that reflect different clothes washer equipment options. Each card describes a separate clothes washer based on the six washer attributes determined from the focus groups. Respondents rank the cards from most to least preferred. This ranking information is used to estimate the probability of purchasing different clothes washer options based on the equipment characteristics.

Conjoint analysis has the advantage of presenting washer characteristics simultaneously, which requires the respondent to make tradeoffs between attributes. By presenting washer attributes simultaneously, respondents must decide which features are most important, much as they would if they were actually shopping for a new clothes washer. Past experience indicates that the most successful conjoint designs limit each exercise to ranking 16 cards at a time with 4 to 6 features on each card. Including more cards or additional attributes tends to overwhelm respondents and results in less reliable data. For these reasons, the clothes washer conjoint was designed with 16 cards with 6 attributes shown on each card.

In addition to empirically determining the value consumers placed on each clothes washer attribute included on the cards, the conjoint method enabled DOE to estimate the effect each washer attribute has on the decision to make a clothes washer purchase. Upon completing the rankings, the respondents were asked to determine which clothes washers they would actually purchase given their current situation. This was done by inserting a 'Purchase Card' in the deck after each respondent completed the ranking process. The cards ranked above the Purchase Card were recorded as the clothes washers the respondent would consider purchasing today while those below the Purchase Card were recorded as clothes washers they would not consider purchasing today. The likelihood of purchasing a clothes washer findings are discussed below.

Table 2. Conjoint Analysis Variable Definitions

Variable	Description
Price	Dollar value of retail price of clothes washer ($400, $450, $650)
Savings	Dollar value of annual water and energy bill savings ($0, $10, $50)
Capacity	Binary variable: zero for standard capacity machine, one for extra large capacity
Door Placement	Binary variable: zero for front loader, one for top loader
Wash Temp	Binary variable: zero for 'cold/warm', one for 'cold/warm/hot' wash/rinse temperature options
Laod Size	Binary variable: zero if there is no load size adjustment option, one if there is.

Table 2 shows the six clothes washer features used in the conjoint analysis as well as the attribute levels. The values used for each variable were chosen to correspond to a standard efficiency clothes washer, a medium efficiency machine (23 percent efficiency improvement) and a high efficiency machine (46 percent efficiency improvement). The order in which the attributes were presented on each card was varied across the groups to avoid any potential bias due to the card presentation.

Session participants were also asked to complete a short survey. The survey gathered additional demographic information and asked for responses to different clothes washer purchase and repair scenarios. The information from the survey was used to divide the sample into various demographic groups as well as provide an additional source of information to help verify the results obtained from the conjoint analysis.

As with the focus groups, one of the goals of the conjoint analysis was to utilize a nationally representative sample containing several different geographic regions. As a result, the conjoint sessions were conducted in four different regions: Washington, DC, Dallas, TX, Madison, WI, and San Francisco Bay Area, CA. The sample was divided so that approximately 100 respondents were recruited from each of these regions. The final sample totaled 435 respondents from these four regions. As with the focus groups, the conjoint session participants were required to be the person that generally did the laundry for their household and each participant was paid a $50 incentive.

The data collected from the conjoint sessions were used to estimate two different models. The first model is referred to as the *Equipment Choice model* and the second model is referred to as the *Purchase model* throughout this paper. Each model provides a different means for examining the value that consumers place on the different clothes washer attributes.

Random Utility Model

Both the equipment choice model and the purchase model are derived from the Random Utility Model (RUM) framework.[2] In the RUM, the utility of any washer choice i can be divided into an observable and non-observable component:

$$U_i = V_i + \varepsilon_i$$

Where U_i = Total utility associated with choice i
V_i = Observable portion of total utility for choice i
ε_i = Unobserved random component of utility

From this, the observable portion of utility is modeled as a function of washer characteristics:

$$V_i = \beta' X_i + \varepsilon_i$$

Where X_i = Observed characteristics of washer choice i
β = Parameters to be estimated
ε_i = Random error, assumed to be distributed logistic in this application.

[2] The Random Utility Model framework is one of the most common utility models used in discrete choice analysis. See, for example, Madalla (1983) for a detailed statistical discussion and Freeman (1993) for examples of how this model is used to quantify the value placed on environmental goods.

The implication is that for a given set of available choices, an individual chooses the clothes washer that will provide the greatest amount of utility based on the characteristics of each choice. In effect, the consumer is modeled as choosing across bundles of clothes washer characteristics, with the consumer ultimately choosing that bundle that provides that maximizes utility. For example, given two clothes washer choices A and B, A will be chosen over B if the characteristics of choice A provide a higher level of utility. Thus, observed utility provides an indication of total utility, or:

$$\beta' X_A > \beta' X_B \rightarrow V_A > V_B \rightarrow U_A > U_B$$

This choice structure underlies both models described in this paper. One must keep in mind, however, that the utility measure $\beta' X_i$ is a relative measure of utility based only on those observable components that could be included in the model. As discussed, the models used in this analysis are based on the six attributes used in the conjoint sessions that were identified during the focus groups as being among the most important features. As a consequence, the estimate of V_i is a partial measure of utility used to determine the relative value placed on attributes, and not a cardinal measure of the total utility associated with each choice. For example, if the estimate of $\beta' X$ for choice A is "4" and "2" for choice B, we can infer that A is preferred to B but we cannot assume that A is preferred *twice as much* as B.

To avoid confusing the estimate of $\beta' X_i$ with a cardinal estimate of total utility, estimation results are presented in terms of relative importance statistics and purchase probabilities rather than utility levels. As shown below, this allows for a more direct comparison of the relative importance of attributes through an analysis of purchase scenarios and the effect that changes in attributes have on the likelihood of purchasing a clothes washer.

Equipment Choice Model

The equipment choice model analyzes the influence of a specific equipment option on the choice of a clothes washer, given that the decision to purchase a machine has already been made. In the conjoint analysis sessions, the respondents ranked 16 clothes washer cards from most preferred to least preferred. When all the conjoint data were collected, the card rankings were regressed against the attribute levels on the cards using an exploded logit model.[3] The coefficient estimates from this model show the influence each characteristic has on the rankings.

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[3] The exact model specification is shown in detail in "Analyzing Consumer Behavior for Setting Energy Efficiency Program Priorities" by Torok and Cavalli, published in this issue of the ACEEE proceedings. Since their paper was presented in the same ACEEE conference session, the model functional form and discussion was omitted from this paper for brevity at the request of the session moderator. A detailed statistical discussion of the exploded logit and its use in conjoint analysis can be found in "Logit Models for Sets of Ranked Items", Nicholos Christakis and Paul Allison, *Sociological Methodology*, Volume 24, 1994, pp. 199-228.

The estimated utility of each choice is calculated by inserting attribute values into the regression equation and multiplying them by the coefficient estimates:

$$\text{Estimated Utility} = V_i = b^*\text{Price}_i + b^*\text{Savings}_i + b^*\text{Capacity}_i + b^*\text{Door}_i + b^*\text{WashTemp}_i + b^*\text{LoadSize}_i$$

Where b is the coefficient estimate for each variable.

The estimation results for the equipment choice model are shown in Table 3. As expected, the coefficient estimate for price is negative and significant and the estimate for savings is positive and significant. Regarding door placement, respondents indicated a preference for top-loaders over front-loaders. A positive coefficient for 'Capacity' indicates consumers prefer extra-capacity machines to standard capacity. Having a hot water wash option was attractive, as was the ability to adjust the water level to match the size of the load. All of these coefficients are significant at the 1 percent level of significance.

Table 3. Equipment Choice Regression Coefficients

Variable	Coefficient Estimate	Standard Error	Significance Level
Price	-0.004	0.000	1%
Savings	0.010	0.001	1%
Capacity	0.248	0.024	1%
Door Placement	0.383	0.024	1%
Wash Temp	0.614	0.024	1%
Load Size	0.852	0.024	1%

While coefficient estimates provide some information on the influence of the variable on total utility, it is misleading to look at only the coefficient to gauge the influence of that variable. For example, the savings coefficient is ten times the magnitude of the price coefficient since savings is measured in tens of dollars and price in hundreds of dollars. Only looking at the magnitude of the coefficients would give the misleading impression that savings is considered much more important than price.

To address this issue, relative importance statistics were calculated that combine both the coefficient and attribute value to get an overall measure of the influence on utility. This statistic measures each feature's contribution to the observed portion of utility based on the six attributes included in the conjoint analysis. Using the coefficient estimates and the values for the feature variables used in the conjoint analysis, the importance statistic is defined as:

$$\text{Imp}_i = \frac{\Delta Ui}{\Delta U} = \frac{\text{Maximum utility change due to feature i}}{\text{Maximum utility change from all features combined}}$$

The relative importance statistic is used to show the relative value placed on each attribute, as well as how these values change across different demographic subgroups.

Table 4. Relative Importance Statistics for Demographic Subgroups

Variable	Full Sample	Low Income	65 & Older	18-24 yrs old	Recent Purchasers	Have Tried Horizontal Axis	Would Consider Purchasing H-Axis Machine	Would Not Consider Purchasing H-Axis Machine
Price	26%	30%	22%	31%	22%	26%	26%	25%
Savings	14%	16%	11%	19%	9%	13%	13%	9%
Capacity	7%	8%	5%	9%	6%	8%	8%	5%
Door Placement	11%	10%	13%	11%	11%	9%	9%	20%
Wash Temp	18%	16%	19%	13%	19%	19%	19%	15%
Load Size	25%	20%	30%	16%	32%	26%	24%	26%

Table 4 provides a comparison of the relative importance statistics calculated for different demographic subgroups. The first column shows the importance statistics for the entire sample, the other columns show the statistics for different demographic subgroups. Recent purchasers are defined as those that purchased a new clothes washer within the last two years and low-income households are those with annual incomes of $25,000 or less.

As expected, price was among the most important features considered by all demographic groups. The relative importance statistic for price was 26 percent for the full sample and ranged from 22 to 30 percent for the different demographic subgroups. Having an adjustable load size option, however, was considered almost as important as price, with an importance statistic ranging from 16 to 32 percent across the subgroups.

Based on relative importance, savings was ranked fourth of the six washer attributes used in the conjoint. For the full sample, relative importance or savings was 14 percent. The youngest demographic group placed the highest importance on savings with a relative importance statistic of 19 percent. For those that had recently purchased a machine, or that would not consider purchasing a horizontal axis machine, importance placed on savings was the lowest at 9 percent. Not surprisingly for this latter group, more importance was placed on door placement, as these respondents indicated both in the survey and in their card rankings that having a front loading machine would be undesirable.

The relative importance results are derived from a situation that emphasizes the tradeoff across attributes similar to what consumers experience when actually making a clothes washer purchase. The resulting importance statistics provides a general indication of the value placed on energy efficiency. The following discussion of the purchase model illustrates how the conjoint information can be used to estimate a dollar value for the willingness to pay for energy efficiency.

Purchase Model

After the respondents had completed ranking their cards during the conjoint analysis, they were asked to place the Purchase Card in the card set to indicate which of the 16 clothes washers indicated on the cards they would actually considering purchasing. Based on this information, the probability of making a purchase was estimated based on the attributes ~~on~~ the cards above and below the Purchase Card. In equation form

$$\text{Purchase (0,1)} = \alpha + \beta\text{'Price}_i + \beta\text{'Savings}_i + \beta\text{'Capacity}_i + \beta\text{'Door}_i + \beta\text{'WashTemp}_i + \beta\text{'LoadSize}_i + \varepsilon_i$$

Where Purchase = 1 if card is ranked above the Purchase Card, 0 if ranked below. The other variables are defined as before in the equipment choice model and the error term is assumed to be distributed logistic.

Table 5. Purchase Model Coefficient Estimates

Variable	Coefficient Estimate	Standard Error	Significance Level
Intercept	-0.949	0.224	1%
Price	-0.007	0.000	1%
Savings	0.029	0.002	1%
Capacity	0.452	0.072	1%
Door Placement	0.698	0.075	1%
Wash Temp	1.438	0.071	1%
Load Size	1.809	0.071	1%

Table 5 shows the coefficient estimates for the purchase model using the entire sample. As these results indicate, the coefficient estimates are similar to those found in the equipment choice model used to estimate relative importance statistics. All of the coefficient estimates are statistically significant at the 1 percent level.

The probability of making a clothes washer purchase was calculated by combining the coefficient estimates with the six washer attributes and using the logit probability function

$$\text{Prob(Purchase)} = \exp(\beta\text{'X}) / (1 + \beta\text{'X})$$

Where β'X reflects the sum of the coefficient estimates (shown in Table 5) and variable values used in the conjoint analysis. By using different values for price, savings, and the equipment features to simulate different efficiency levels, this equation was used to determine the coverall effect of a new standard on the utility of clothes washers to consumers.

Table 6. Purchase Scenarios

Sample Group	Standard Efficiency	Medium Efficiency	High Efficiency Front Load	High Efficiency No Hot Water	High Efficiency Front Load, Contant Price
Full Sample	0.59	0.58	0.36	0.21	0.75
Low Income	0.65	0.63	0.41	0.26	0.78
Elderly	0.59	0.59	0.39	0.26	0.66
Young	0.64	0.61	0.29	0.28	0.76
Recent Purchasers	0.55	0.54	0.33	0.17	0.67
Would Consider H-axis	0.56	0.55	0.42	0.21	0.78
Have Tried H-Axis	0.57	0.56	0.39	0.19	0.78

Table 6 shows probability estimates for different purchase scenarios by sample subgroups. These purchase scenarios are calculated by modifying the values for the clothes washer variables to reflect standard efficiency, medium efficiency, and several high efficiency equipment options. The standard efficiency option assumes a price of $400, no energy and water savings, and a top loading machine. The medium efficiency washer has a price of $450 and energy and water savings of $10 annually, and is a top loading machine. This is consistent with a 23 percent improvement in efficiency. The high efficiency equipment options have a price of $650, annual savings of $50, and are either front loading or have no hot water. These high efficiency options are designed to coincide with a 46 percent improvement in efficiency. To control for the effect of price in these scenarios, the high efficiency option is also calculated with holding price constant at $400, while having a front loading machine with $50 annual savings.

The first row of Table 6 shows the purchase probability estimates for the full sample for a variety of washer efficiency levels. For the full sample, the initial likelihood of purchase estimate is 0.59, meaning that 59 percent of those surveyed would be willing to purchase the standard efficiency clothes washer. This provides a starting point from which to compare changes in attributes and the effect these will have on the likelihood of purchase. In this sense, examining the changes in purchase probability reflects the change in utility, since lower utility washer configurations will have a lower likelihood of being purchased.

The high efficiency options tend to have much greater effect on the likelihood of purchase. This results from the greater change in price as well as changing the design of the machine to be either a front loader or to have the machine clean without using hot water. As shown in Table 6, a high efficiency front loading washer at a price of $650 and annual savings of $50 will decrease the likelihood of purchase from 0.59 to 0.36, a decrease of 39 percent. If the machine is designed to run without hot water instead of being a front loader, the decrease is even greater. In this case, the purchase probability falls 64 percent to 0.21.

The far right columns of Table 6 show the likelihood of purchase for high efficiency machines that have the standard efficiency ($400) price. In the case where savings is $50 annually and the machine is a top loader, then the purchase probability is estimated to increase from 0.59 to 0.75. This shows that the increase in savings more than offsets the decrease in utility due to switching from a front loader to a top loader. This suggests that having a front loading, high efficiency clothes washer without a substantial increase in price would result in a net gain in utility, other things equal.

To address the DOE concerns about consumer utility, the model results were used to find the high efficiency break-even price. The high efficiency break-even price is the price at which the switch to high efficiency results in no change in consumer utility. Stated another way, high efficiency clothes washers offered at the high efficiency break-even price should see no change in overall sales compared with the standard efficiency clothes washers, other things equal.

The calculations for the high efficiency break-even price were done for both the high efficiency options. For a front loading, high efficiency machine, the breakeven price is $510, so that the likelihood of purchase remains at 0.59 with the $50 annual savings and front loading design. The break-even price is lower when hot water is removed, since removing hot water has a greater negative impact on utility. For a top loading machine with a $50 savings but with no hot water, the break even price is $400. Stated another way, this suggests that consumers would be willing to forego $50 a year to be able to have hot water as an option for washing clothes. This finding is consistent with the relative importance statistics, where water temperature settings had a higher relative importance rating than door placement for almost all demographic groups.

Table 7. Estimated Willingness to Pay for Energy Efficiency

Sample Group	Annual Savings	Equivalent Change in Price
Full Sample	$50	$225
Low Income	$50	$190
Elderly	$50	$250
Young	$50	$170
Recent Purchasers	$50	$200
Would Consider H-axis	$50	$240
Have Tried H-Axis	$50	$220

Finally, the purchase probabilities were used to estimate the value placed on energy efficiency, while holding all other clothes washer features constant. This was done by manipulating the purchase probability to find a price level that has the same effect on the purchase probability as the high efficiency savings level of $50 per year. Since the effect on the likelihood of purchase is the same, the change in purchase price can be used as an estimate of willingness to pay for energy efficiency.

The results of this exercise are shown in Table 7. For the full sample, the estimated willingness to pay for a $50 a year savings in energy and water costs is $225. Stated another way, consumers are just as likely to purchase a standard efficiency washer with a price of $400 and zero annual savings as they are to purchase a washer at $625 that saves them $50 per year in energy and water costs. The same calculation was done for the other demographic groups. Low income and young people are less willing to pay for energy efficiency, which is as expected given income constraints. The elderly and those that indicated that they would consider a horizontal axis machine had the highest willingness to pay, ranging from $240 to $250.

Conclusions

Conjoint analysis enables energy efficiency advocates to determine the value consumers place on energy efficiency by examining the tradeoffs made between the purchase price and annual savings. In the conjoint analysis study reviewed in this paper, we were able to determine that the full sample is willing to pay an additional $225 on the purchase price of a new washer to save $50 annually in washer-related energy and water costs, assuming no other changes to the four other washer attributes examined in the conjoint analysis.

The decline in energy prices over the last two decades has posed a significant challenge for energy efficiency advocates, as the economic benefits of advances in energy efficiency have become less evident to both consumers and manufacturers. In this context of relatively low energy prices, manufacturers are reluctant to increase the costs of their products to improve their energy efficiency unless they have reliable empirical evidence on what consumers are willing to pay to reduce the product's energy-related costs. Conjoint analysis is a sound analytical method that can help energy efficiency advocates and manufacturers meet the challenge of empirically estimating what consumers are willing to pay for gains in energy efficiency.

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