TUTORIAL

# Conjoint

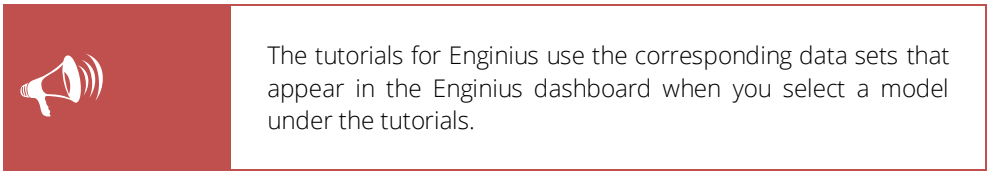
# Overview

Conjoint analysis is an approach for measuring customers' preferences; it is particularly useful for analyzing and predicting customers' responses to new products and new features of existing products. With conjoint analysis, companies can decompose customers' preferences for products and services (provided as descriptions, visual images, or product samples) into the "partworths" value associated with each level of each attribute or feature of the product category. Companies can then use the estimated partworths to predict customers' preferences and choices for any combination of attribute options, determine the optimal product concept, and identify market segments that value a particular product profile highly.

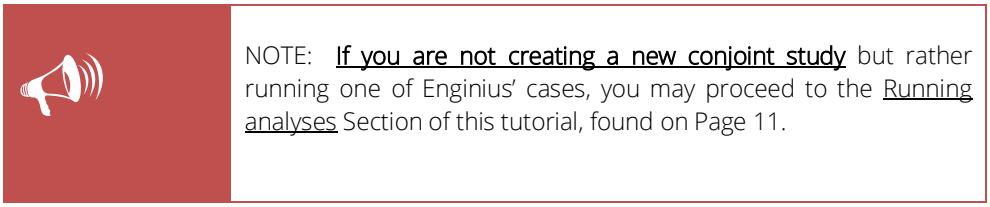
Conjoint analysis also helps firms answer such questions as:

- ✓ How much are our customers willing to pay for an extended warranty?
- ✓ What factors are most important for driving customers to choose our product?
- ✓ What new product that we could introduce will have the highest realizable market share?
- ✓ If we must choose between two different features to introduce in the next generation of our products, which one would have the most impact on customers' choices?
- ✓ In our market, what proportion of customers are price sensitive? What proportion of customers are quality-driven in their purchase decisions?

# Getting Started




## Creating a conjoint study template



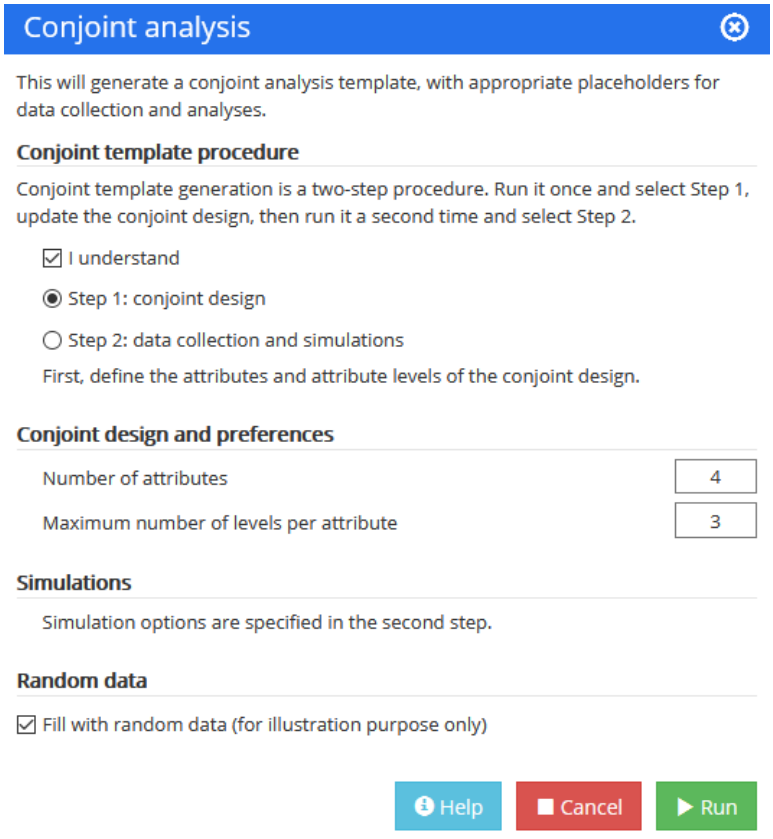
## Step 1 Creating a study design template

A conjoint study is a multi-step process. It starts with the assumption that any product can be denoted as a bundle of attribute levels. In **Step 1**, you will enter the attributes and levels associated with a product category. In **Step 2**, the Enginius software will use those attributes and levels to create product profiles to be evaluated by your customers. Enginius uses an Addelman design to create the minimum number of profiles required to extract the partworths correctly (for more details, see Conjoint Technical Note at https://www.enginius.biz/index.php/instructors/teaching-resources/technical-notes/). Note that if you change any of the product profiles generated by the system, or remove any product profiles, the software may no longer provide accurate results (or any results at all).

An **attribute** is a general property or characteristic of a product category that you can use to build and describe alternative products or services. "Color," "Price," "Brand," or "Quality" are examples of attributes.

After you have described the attributes, in the next step, you must enter the available levels for each attribute. Whereas an **attribute** represents a characteristic such as color, price, or warranty, the **levels** are the particular values that an attribute can take, such as red, $20, or 1-year warranty. You need to specify at least two levels for each attribute. The screen capture below shows the dialog box that allows you to generate an **Enginius data template** for Conjoint Analysis.

**Note: Generating a Conjoint template is a 2-step process. Both steps need to be completed before any analysis can be done.**



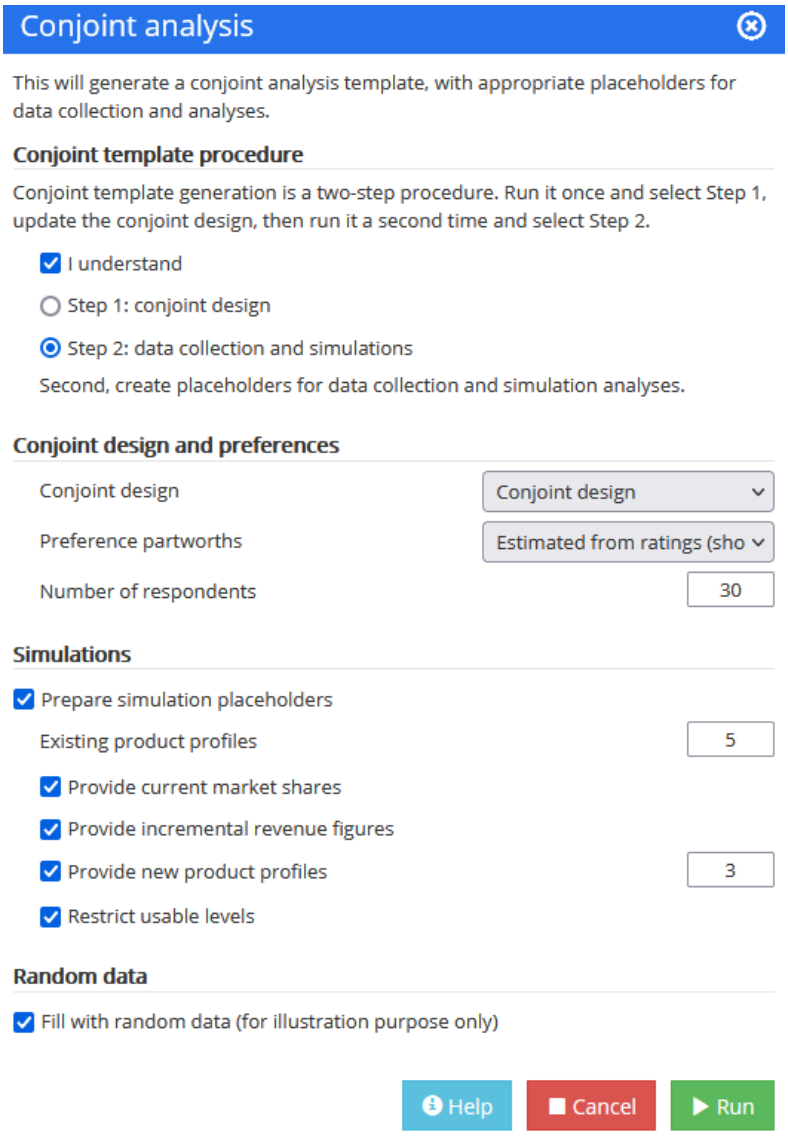

The screen capture below shows an example of Attributes and Levels from Step 1 of the template process.

Conjoint design

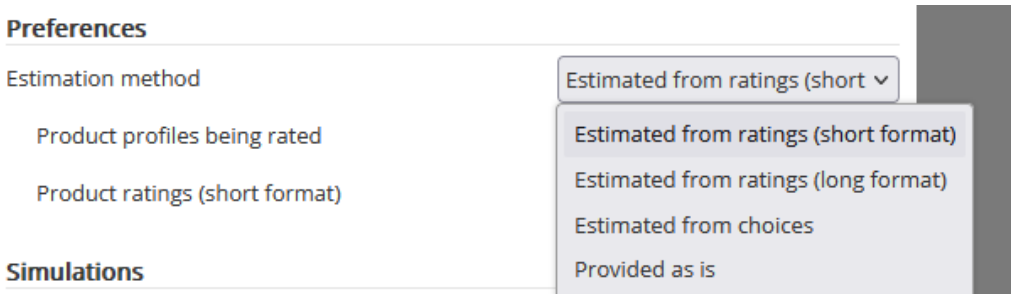
| | Attribute A | Attribute B | Attribute C | Attribute D | |
|---|---|---|---|---|---|
| Level 1 | Level A1 | Level B1 | Level C1 | Level D1 | |
| Level 2 | Level A2 | Level B2 | Level C2 | Level D2 | |
| Level 3 | Level A3 | | Level C3 | | |
| | | | | | |

For ease of interpretation, the above matrix should be modified with the actual names of attributes and levels. For further illustration, we will use the data from the Office Star example for the attributes and levels.

Once done, Step 2 of the template process can be completed, as shown below. The several options shown on this dialog box are explained in the following section. Your particular study may not need all of the options presented below.



In the above dialog box, review the selections available via the drop-down arrow in the Preference partworths field:




Preference partworths can either be estimated from ratings or ranks (provided in "short" or "long" format) or estimated from choices (for choice based conjoint), or "Provided as is" (as a data block containing estimated partworths).

(1) Short format ratings are used when all respondents evaluate an identical set of product profiles. Because of the similitude in survey format and content, the characteristics of each rated profile can be specified only once for the entire analysis (as opposed to once for each respondent). Hence the data is less verbose and easier to input. However, the constraint that all respondents be provided the same set of profiles for evaluation may be limiting in some situations. The ratings or rankings are then used to infer respondents' partworths (preferences). There is an example of the set of profiles for the Office Star example.

(2)

| \ | Profile 1 | Profile 2 | Profile 3 | Profile 4 | Profile 5 |
|---|---|---|---|---|---|
| **Location** | Within 5 to 10 miles | Within 5 to 10 miles | Less than 2 miles | Less than 2 miles | Within 2 to 5 miles |
| **Office supplies** | Very large assortment | Large assortment | Limited assortment | Large assortment | Limited assortment |
| **Furniture** | Office furniture | Office furniture | Office furniture | No furniture | No furniture |
| **Computers** | No computers | No computers | No computers | No computers | No computers |

Each respondent will be given the same set of profiles to rate or rank.

(In this example, each respondent will be asked to rate the same 13 profiles where each profile is a combination of attributes and levels -- we have only shown the first five profiles above.)

(3) Long format ratings are used when each respondent rates different conjoint profiles (shown below). These ratings are then used by Enginius to infer respondents' partworths. With this option, each respondent could be exposed to different profiles, or even to a different number of profiles (i.e., each respondent has their own customized or randomized questionnaire). The long format ratings require one data block with each row containing the profile that a respondent rates. Note that the Enginius template generation process will generate identical bundles for each respondent. If you would like to use different bundles for different respondents, you would need to develop these bundles yourself.

In the example below, each respondent is asked to rate a different set of profiles.

| Id | Respondent | Location | Office supplies | Furniture | Computers | Rating |
|---|---|---|---|---|---|---|
| 1 | 1 | Within 2 to 5 miles | Very large assortment | No furniture | Software only | 24 |
| 2 | 1 | Within 5 to 10 miles | Large assortment | No furniture | Software and computers | 13 |
| 3 | 1 | Less than 2 miles | Very large assortment | No furniture | No computers | 33 |
| 4 | 1 | Less than 2 miles | Large assortment | Office furniture | No computers | 89 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 16 | 2 | Within 2 to 5 miles | Large assortment | Office furniture | No computers | 24 |
| 17 | 2 | Less than 2 miles | Large assortment | Office furniture | Software only | 41 |
| 18 | 2 | Within 5 to 10 miles | Limited assortment | No furniture | Software and computers | 60 |
| 19 | 2 | Less than 2 miles | Limited assortment | No furniture | Software only | 32 |

Conjoint ratings (long format): Each respondent can be given a different set of profiles to rate.

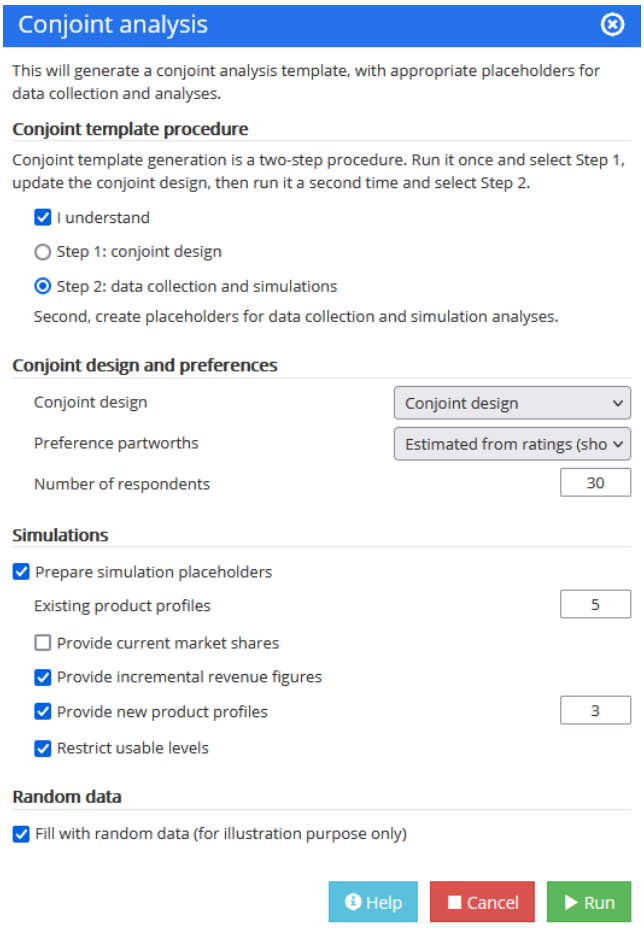
(4) **Estimated from choices** is an option that you can use for Choice Based Conjoint (CBC) analysis wherein respondents are presented with sets of product profiles from which they pick the most preferred option from a given set. Here is an example of a choice set from which a respondent selects the most preferred option (A "no choice" could be included in a set of product profiles presented to a respondent). Different respondents could be provided with different sets of profiles if these sets are carefully designed to cover the spectrum of attributes and levels.

Which one of the following stores are you most likely to patronize (click one of the check boxes)?

| Attribute | Store 1 | Store 2 | Store 3 |
|---|---|---|---|
| Location | Within 5 to 10 miles | Within 2 to 5 miles | Within 5 to 10 miles |
| Office supplies | Large assortment | Very large assortment | Limited assortment |
| Furniture | Office furniture | Office furniture | No furniture |
| Computers | No computers | Software only | Software and computers |

(5) **Select Provided as is** when the respondents' partworths have already been estimated or are provided by the user. Such partworths could be from estimates previously computed using Enginius, or from an external conjoint study that is not accessible to the user.

You can use the template design to set up the parameters for subsequent analyses by choosing the appropriate options in the **Simulations** section of the dialog box shown below. (Note: You can modify most of these options when running an analysis, without having to recreate a template).




Using this dialog box you can limit the number of **product profiles** (placeholders) to denote products that already exist in the current market, choose to include or exclude **incremental revenue** data, include **new product profiles** and **restrict usable levels** in the resulting template.

**Existing product profiles** can be used to specify the set of competitors already in the market:

Existing competitors

| \ | Location | Office supplies | Furniture | Computers |
|---|---|---|---|---|
| Office Equipment | Within 2 to 5 miles | Large assortment | Office furniture | Software and computers |
| Department Store | Within 2 to 5 miles | Limited assortment | No furniture | Software only |

**Incremental Revenue** allows you to specify incremental revenue for each attribute/level specified in the Conjoint design restriction table. Incremental Revenue is an optional table which will enable you to run simulations based on computing contribution, instead of market shares. For each attribute, the base level has an incremental revenue value of 0. The base product is the combination of the base attribute levels (here, Level 1 for Location, Level 2 for Office supplies, Level 2 for Furniture, and Level 1 for Computers).

**Incremental revenue**

| \ | Location | Office supplies | Furniture | Computers | |
|---|---|---|---|---|---|
| Level 1 | 0 | -15 | -30 | 0 | |
| Level 2 | 70 | 0 | 0 | -10 | |
| Level 3 | 100 | 20 | | -40 | |
| | | | | | |

* This table summarizes how much more revenue (+) or cost (-) would be generated by each option, compared to a base option.

Provide new product profiles allows you to specify new product options that could be introduced to the market to compete with the existing offerings. Each attribute must contain one level for each attribute from your conjoint design.

**New options being considered**

| \ | Location | Office supplies | Furniture | Computers |
|---|---|---|---|---|
| Office Star 1 | Less than 2 miles | Large assortment | No furniture | Software and computers |
| Office Star 2 | Within 2 to 5 miles | Large assortment | Office furniture | No computers |

Restrict usable levels allows you to restrict attribute levels available when running a simulation to select one or more optimal products. This feature is useful for eliminating infeasible product profiles from being considered in simulations for selecting the best products.

**Conjoint design restrictions**

| \ | Location | Office supplies | Furniture | Computers | |
|---|---|---|---|---|---|
| Level 1 | Within 5 to 10 miles | Very large assortment | Office furniture | No computers | |
| Level 2 | | Large assortment | No furniture | Software only | |
| Level 3 | | Limited assortment | | Software and computers | |
| | | | | | |

* This table lists attribute levels that can be used in the search for an optimal product. In this example, only stores located within 5-10 miles are possible.

## Step 2 Data collection

Data for a conjoint study is usually obtained using a data collection instrument designed via the Survey tool available at Enginius, or via other survey tools such as Qualtrics and Survey Monkey. Data generated using the Enginius survey tool can be directly loaded into Enginius for analysis. For data collected using other tools, the data should be formatted appropriately for use within Enginius. By completing the surveys, respondents provide ratings, rankings, or choices to reflect their preferred product profiles. If respondents are asked to rank a set of profiles presented to them, then the data should be structured (if needed via suitable data transformation) so that their most preferred profile has the highest numeric value. If two profiles are equally preferred, they can have the same rank.

## Step 3 Entering your data

The data obtained from respondents are then entered/imported into Enginius for further analysis. The table below summarizes the ratings (on a scale of 1 to 100) obtained from a sample of 9 respondents for the example template.

| Customer ratings (short format) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| \ | Profile 1 | Profile 2 | Profile 3 | Profile 4 | Profile 5 | Profile 6 | Profile 7 | Profile 8 | Profile 9 | Profile 10 | Profile 11 | Profile 12 | Profile 13 |
| Respondent 1 | 58 | 59 | 87 | 35 | 24 | 80 | 86 | 3 | 100 | 92 | 66 | 44 | 11 |
| Respondent 2 | 5 | 9 | 33 | 38 | 16 | 22 | 34 | 8 | 100 | 86 | 63 | 95 | 61 |
| Respondent 3 | 4 | 10 | 22 | 20 | 4 | 26 | 44 | 28 | 100 | 86 | 84 | 90 | 80 |
| Respondent 4 | 56 | 31 | 26 | 39 | 17 | 90 | 43 | 39 | 75 | 75 | 36 | 91 | 27 |
| Respondent 5 | 68 | 48 | 33 | 73 | 18 | 67 | 24 | 40 | 78 | 62 | 15 | 99 | 16 |
| Respondent 6 | 50 | 40 | 77 | 63 | 19 | 65 | 75 | 12 | 87 | 55 | 26 | 71 | 0 |
| Respondent 7 | 60 | 65 | 91 | 44 | 23 | 67 | 83 | 5 | 100 | 84 | 64 | 43 | 12 |
| Respondent 8 | 11 | 12 | 25 | 35 | 10 | 14 | 22 | 10 | 99 | 83 | 68 | 99 | 69 |
| Respondent 9 | 0 | 1 | 24 | 26 | 8 | 28 | 45 | 23 | 99 | 82 | 74 | 99 | 75 |

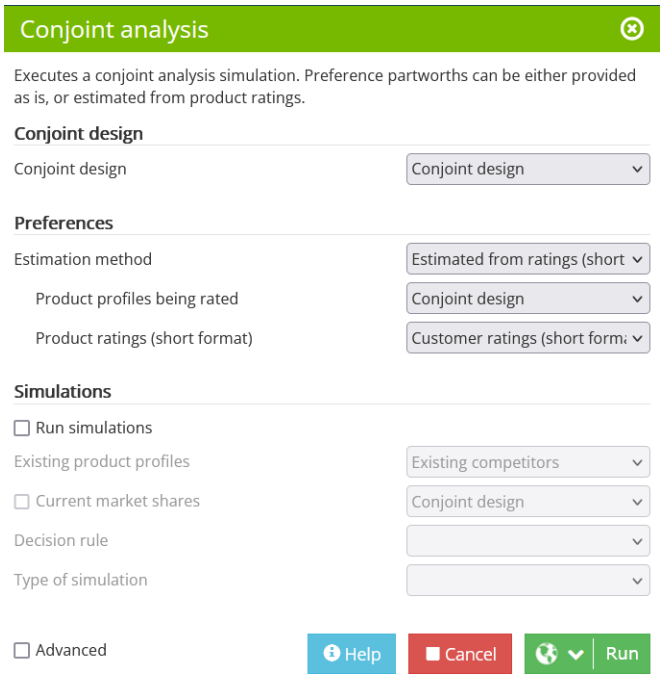
* Ratings data for short data format

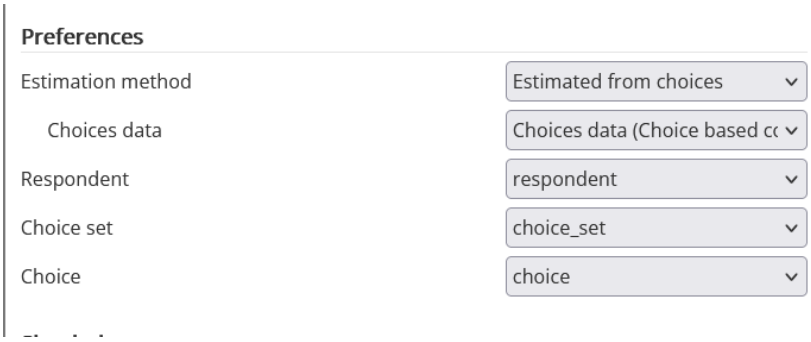
For choice-based conjoint, the data is summarized as shown below for the Office Star example. Here the "Choice column" indicates the profile selected by a respondent, with its value equal to 1 to indicate the product profile that was chosen by the respondent, and the choice values for the other profiles in a choice set are noted as equal to 0:

| Choices data (Choice based Conjoint) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Record** | **Respondent** | **Choice_set** | **Choice** | **Location** | **Office supplies** | **Furniture** | **Computers** |
| 1 | 1 | 1 | 0 | Within 5 to 10 miles | Large assortment | Office furniture | No computers |
| 2 | 1 | 1 | 0 | Within 2 to 5 miles | Very large assortment | Office furniture | Software only |
| 3 | 1 | 1 | 1 | Within 5 to 10 miles | Limited assortment | Office furniture | Software and computers |
| 4 | 1 | 2 | 0 | Within 2 to 5 miles | Large assortment | No furniture | Software and computers |
| 5 | 1 | 2 | 1 | Less than 2 miles | Very large assortment | No furniture | Software only |
| 6 | 1 | 2 | 0 | Within 5 to 10 miles | Limited assortment | Office furniture | No computers |
| | | | | | | | |
| 43 | 2 | 5 | 0 | Within 2 to 5 miles | Limited assortment | No furniture | Software only |
| 44 | 2 | 5 | 0 | Within 5 to 10 miles | Large assortment | No furniture | Software and computers |
| 45 | 2 | 5 | 1 | Less than 2 miles | Very large assortment | No furniture | No computers |
| 46 | 2 | 6 | 1 | Within 5 to 10 miles | Very large assortment | No furniture | Software only |
| 47 | 2 | 6 | 0 | Within 2 to 5 miles | Large assortment | No furniture | Software and computers |
| 48 | 2 | 6 | 0 | Less than 2 miles | Limited assortment | Office furniture | No computers |

## Step 4 Estimating preference partworths

Respondents' partworths are obtained by converting respondent ratings, rankings, or choices into partworths, estimated for each attribute level for each respondent. For ratings and rankings data, the partworths are computed using regression analysis, and for choice based conjoint, the partworths are computed using Hierarchical Bayes regression. The dialog box selections for estimating partworths are provided below: (1) for using short form ratings, and (2) for choices.




An example output containing the estimated partworths is shown below. The estimated partworths are normalized so that for each attribute, the least preferred level is set to 0, and the sum of the partworths of the most preferred profile is equal to 100.

Preference partworths

| \ | Less than 2 miles | Within 2 to 5 miles | Within 5 to 10 miles | Very large assortment | Large assortment | Limited assortment | Office furniture | No furniture | No computers | Software only | Software and computers |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Respondent 1 | 28.84 | 23.91 | 0 | 3.35 | 4.54 | 0 | 52.97 | 0 | 4.56 | 0 | 13.65 |
| Respondent 2 | 30.76 | 15.35 | 0 | 3.22 | 6.5 | 0 | 1.72 | 0 | 0 | 0.97 | 61.01 |
| Respondent 3 | 14.19 | 0.87 | 0 | 0 | 4.93 | 1.17 | 2.5 | 0 | 0 | 22.82 | 78.38 |
| Respondent 4 | 16.86 | 16.85 | 0 | 46.61 | 21.99 | 0 | 8.86 | 0 | 0 | 16.75 | 27.66 |
| Respondent 5 | 24.27 | 8.64 | 0 | 59.04 | 40.66 | 0 | 0 | 1.5 | 7.84 | 0 | 15.19 |
| Respondent 6 | 47.84 | 16.54 | 0 | 22.7 | 12.41 | 0 | 27.5 | 0 | 1.96 | 0.04 | 0 |
| Respondent 7 | 30.51 | 15.19 | 0 | 0 | 5.92 | 1.07 | 52.97 | 0 | 7.1 | 0 | 10.6 |
| Respondent 8 | 21.99 | 6.15 | 0 | 7.26 | 8.66 | 0 | 0 | 1.15 | 4.14 | 0 | 68.21 |
| Respondent 9 | 23.47 | 8.69 | 0 | 0.15 | 2.36 | 0 | 0 | 0.83 | 0 | 18.77 | 73.34 |

* This table lists, for each respondent, his or her estimated preference partworths, or preferences, for each attribute level. They have been scaled such as the sum of the most preferred levels sum up to 100.

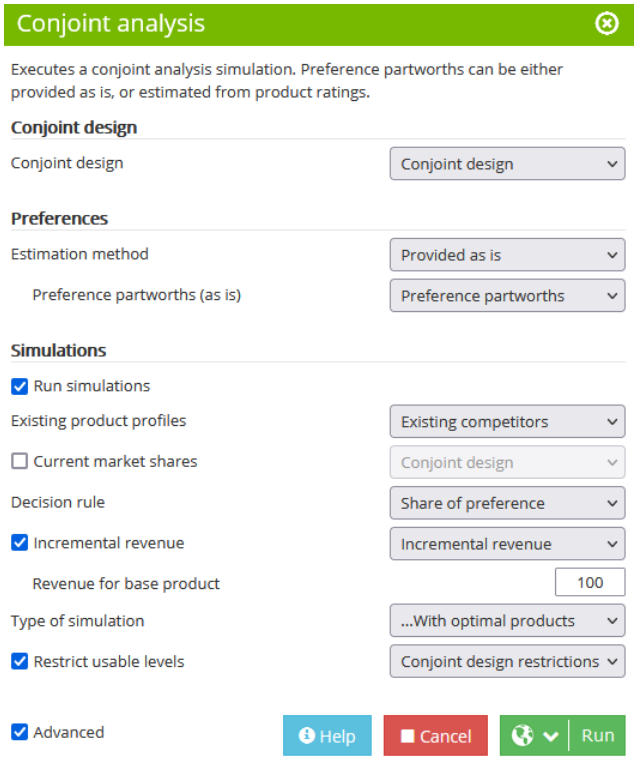
The estimated preference partworths are valuable to analyze in and of themselves. For example, with these estimates you can address such questions as: What are the most important attributes (or features) for a respondent? On average (i.e., across a selected set of respondents) what is the importance of each attribute? and so forth

# Running Analyses

NOTE: The remainder of this tutorial is based on the OfficeStar data which opens when you click on the Tutorials->Conjoint Analysis link from the dashboard.

After partworths have been generated, you may use them for further analysis, without re-estimating partworths every time you run a simulation (unless you include additional respondents to your original data). For running the analysis, Enginius first adds up partworths corresponding to each attribute level present in a product profile to compute the total utility for that product, separately for each respondent.

To run Conjoint analysis on the data you have loaded/prepared, click on the RUN CONJOINT ANALSYSIS button on the left side of the Enginius dashboard.




The above dialog box will allow you to specify the parameters for the analysis.

- Conjoint Design allows you to select the data that describes the design of the conjoint analysis to be run. Note: Enginius allows you to define and name many data blocks, so you could have more than one "design table" in your analysis along with the corresponding data blocks for the data obtained for that design.

- Preferences will allow you to select the Estimation method (for estimation based on rating, ranking, or choice data). If partworths have already been calculated, use the "Provided as is" option. When estimating from short format ratings, you will need to specify the data block for product profiles being rated and the product ratings data block. When estimating using long format ratings, you will only need to specify the product ratings data block as this data block contains both profiles and ratings.

- Simulations allows you to select what simulation parameters should be included in an analysis.

    - Existing product profiles specify the profiles for products already in the marketplace. These may be products or services offered by competitors or by your own company. Including existing options provided by your company allows you to estimate potential cannibalization of an existing product by the new product introduced into the market by your company.

    - Current market share allows you to specify the current market shares of existing products, if known. You can infer a more precise relationship between preferences (preference partworths) and choices (market shares), which enhances the predictive value of your simulations. Of course, you must also know exactly what alternatives already exist.

    - Decision rule allows you to specify how customers decide to choose between different offerings in a marketplace. You should select the best option that applies to your product category and market context:

        - First choice rule: Here each respondent/customer is assumed to select the product that provides the highest utility among competing products and a specific new product concept being evaluated. If customers buy products in the product category infrequently and/or are highly involved in the purchase decision (e.g., house, car, expensive computer), the maximum utility rule is a good option.
        - Share of preference rule: Each respondent's share of choices/purchases of a product is based on their preference for that product, as compared to the total preference for all products in the competitive set. This analysis option is most suitable for products that customers buy frequently and/or for which they are less involved in the purchase decision (e.g., beer, toothpaste).
        - Logit choice rule: The share of each product for each respondent is a function of the weighted utility for that product, compared with the total weighed utility for all products in the competitive set. The weighting uses an exponential function. This analysis option provides an alternative to the share of utility model. This option is available only if you provide information about the market shares of existing products in the segment to which you are targeting the new product (you should select the current market shares option).
        - Alpha rule: It is a weighted combination of the maximum utility rule and the share of preference rule, this method chooses a weight (alpha) that ensures the market shares computed within the simulation are as close as possible to the actual market shares of

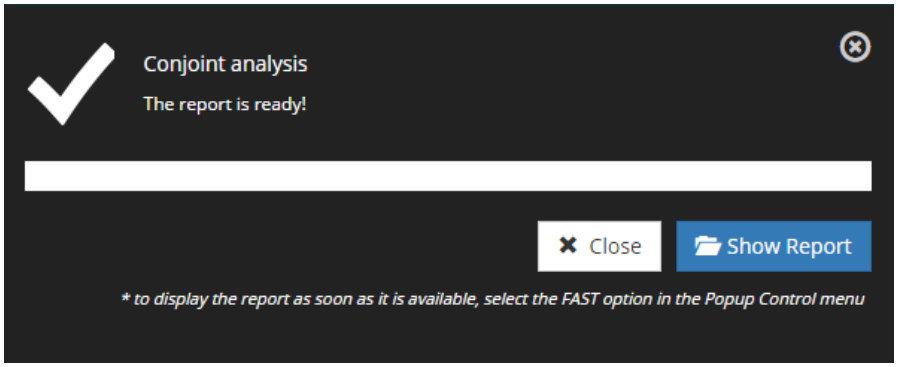
the existing products in the market. This option is available only if you provide information about the market shares of existing products in the segment to which you are targeting the new product (you should select the current market shares option).

- Incremental revenue (advanced option) allows you to incorporate incremental revenue values associated with each attribute and levels. These values are specified as the increase or decrease in revenue corresponding to each attribute and level of a base product.

- Type of simulation allows you to specify whether the simulation will be conducted using the specified set of existing and new products, or whether the simulations would consider all feasible product profiles that could potentially be introduced into the market.
  - Existing product profiles are used to simulate the performance of the existing set of competing products, assuming customers are familiar with all the products and the products are equally widely available for customer purchase.
  - New products from set you have defined. In this case, the simulation introduces one new product at a time into the market along with all existing products to compute the market shares of all products, including the new product.
  - Optimal products tests for all possible combinations of new products and keeps those that lead to the highest market shares (or highest revenues, if you have checked the incremental revenue option), after incorporating existing product profiles in the current market. This analysis helps you identify new opportunities, or "holes," in the market.
  - Restrict usable levels allows you to select which attribute levels will be included in the simulations (controlled in this example by the Conjoint design restriction table).

Depending on the data you have available and the type of analysis you want to perform, you may choose different options than the ones shown in the above selections.

Make the desired selections and click the Run button. The Conjoint analysis will be executed with the chosen selections and a report will be generated. The analysis described below was created with the selections shown above. When an analysis is complete, the following dialog box will appear:

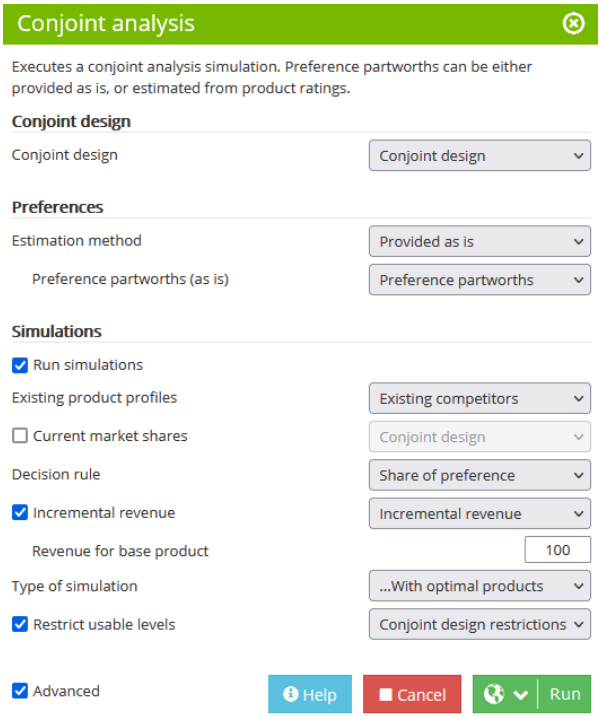



Click "Show Report" and the Conjoint Analysis report will open in a separate tab within your browser.

Every report you run on Enginius is saved in your "Report History", shown at the top of the Enginius Dashboard. Such reports are shown by date run, but will have a generic name such as Positioning Analysis. You may click on each report and rename it so it will be easier to differentiate multiple analyses.

# Interpreting the Results

The following section explains the output produced from the following Run Analysis selections, using the OFFICESTAR: CONJOINT ANALYSIS (FROM PARTWORTHS).



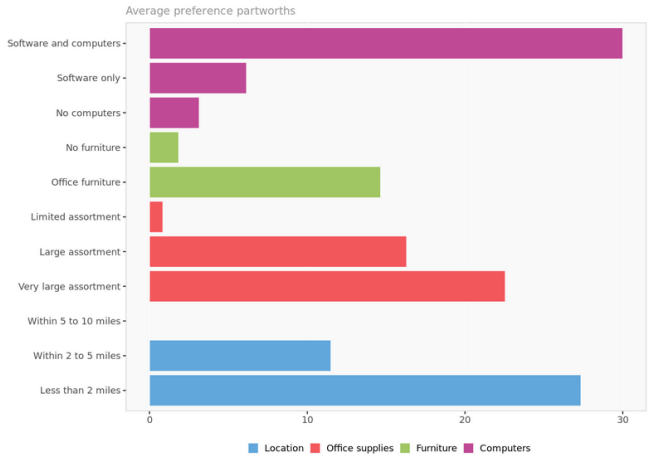

The **Preference partworth section** contains tables, a bar chart and pie chart that show the importance of each attribute and level included in the analysis.

While this example uses pre-generated partworths, if you have respondent ratings (included within the example data) Enginius will generate the needed partworths from the ratings.

The table and bar chart below show the closeness of location, large assortment, office furniture and including both software and computers are important attributes.

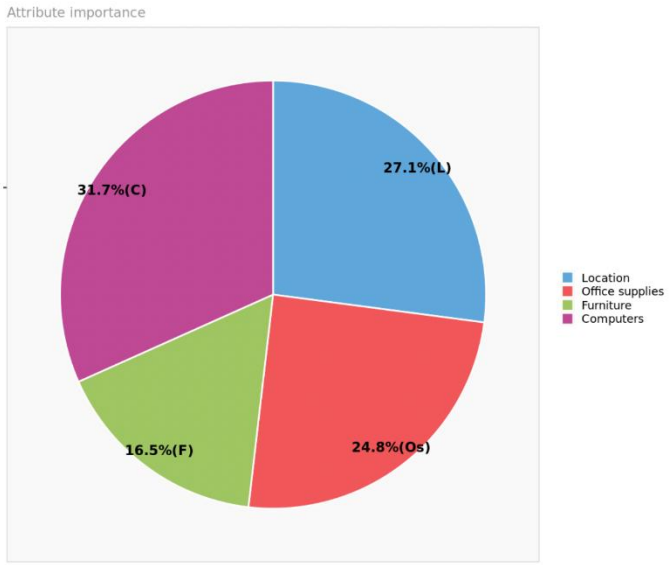
| | Average | Std dev. | Minimum | Maximum |
|---|---|---|---|---|
| **Less than 2 miles** | 27.0 | 10.6 | 14.2 | 49.7 |
| **Within 2 to 5 miles** | 11.7 | 6.4 | 0.6 | 23.9 |
| **Within 5 to 10 miles** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Very large assortment** | 22.6 | 20.7 | 0.0 | 59.0 |
| **Large assortment** | 16.6 | 11.7 | 2.4 | 40.7 |
| **Limited assortment** | 0.9 | 3.4 | 0.0 | 15.3 |
| **Office furniture** | 14.7 | 18.9 | 0.0 | 54.5 |
| **No furniture** | 1.8 | 3.9 | 0.0 | 12.9 |
| **No computers** | 3.4 | 5.2 | 0.0 | 22.2 |
| **Software only** | 5.9 | 8.1 | 0.0 | 22.8 |
| **Software and computers** | 30.1 | 26.3 | 0.0 | 78.4 |

**Preference partworths**. Average and standard statistics for preference partworths.




**Preference partworths**. Average preference partworths for each attribute level.

The pie chart below shows the importance level for each attribute. The importance of an attribute for each respondent is computed as the difference between the partworth of the most preferred level of that attribute for that respondent, and the least preferred level (by default, the least preferred level of each attribute is set to 0). This chart shows the average importance values (the importances are averaged across respondents) of each attribute (the average importance values sum to 100):




**Attribute importance**. Reports the maximum level value for each attribute, reflecting the relative importance of each attribute in driving preferences.

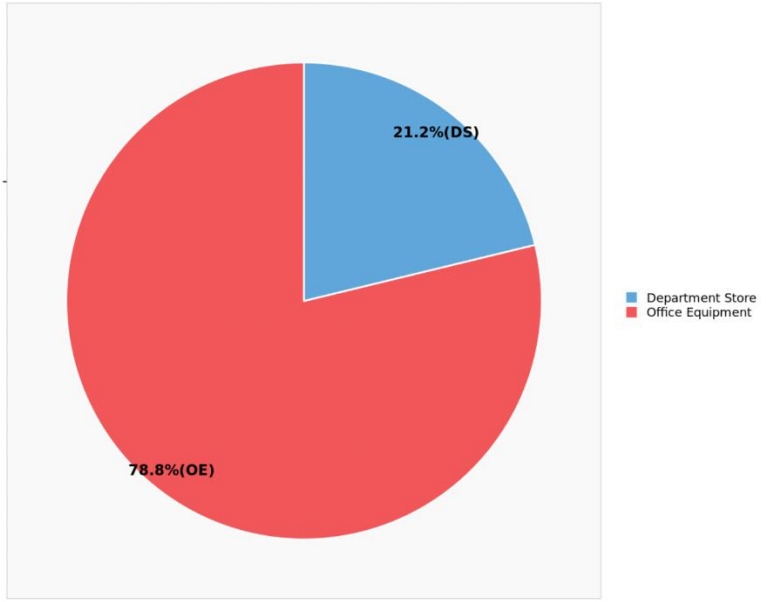
The Simulations with existing products section show the Office Equipment store has a significant advantage over the Department Store included in the analysis.

| | Location | Office supplies | Furniture | Computers |
|---|---|---|---|---|
| **Office Equipment** | Within 2 to 5 miles | Large assortment | Office furniture | Software and computers |
| **Department Store** | Within 2 to 5 miles | Limited assortment | No furniture | Software only |

**Existing products**. Characteristics of products already in the marketplace.

| | Office Equipment | Department Store |
|---|---|---|
| **Predicted** | 78.8% | 21.2% |

**Predicted market shares**.



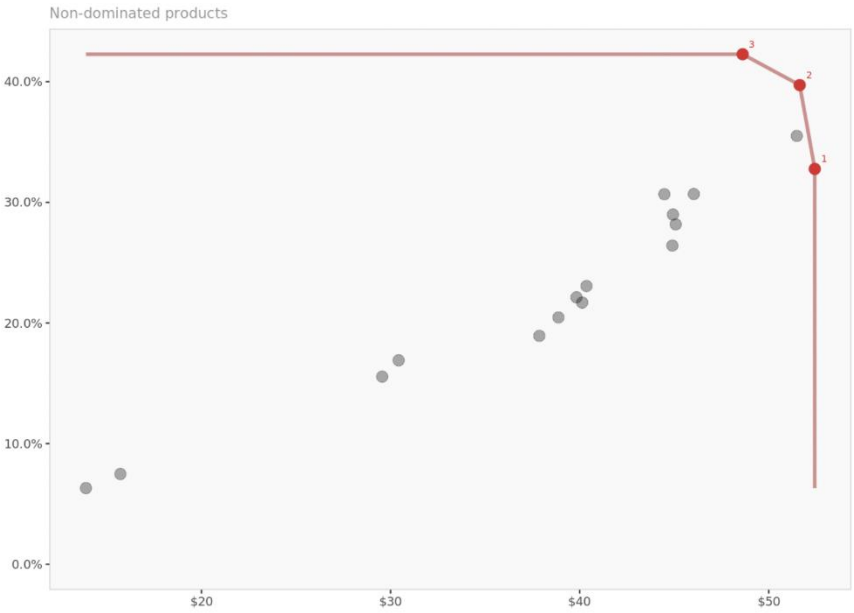

**Predicted market shares.**

The Simulations with optimal product section show the optimal products and how those five products would perform based on the respondent data. As selected within the Conjoint design restrictions data block, only a location within 5 to 10 miles was an available choice.

| | Location | Office supplies | Furniture | Computers |
|---|---|---|---|---|
| **Optimal product 1** | Within 5 to 10 miles | Large assortment | No furniture | Software and computers |
| **Optimal product 2** | Within 5 to 10 miles | Large assortment | Office furniture | Software and computers |
| **Optimal product 3** | Within 5 to 10 miles | Very large assortment | Office furniture | Software and computers |

**Optimal products**. Characteristics of optimal products potentially introduced in the marketplace.

If you selected the Incremental Revenue (advanced) option, you will also see a chart depicting the "Pareto Frontier" and a table that shows Weighted revenue for each optimal product, as shown below. The Pareto Frontier shows the optimal products that are not dominated by any other potential product profile that is considered.



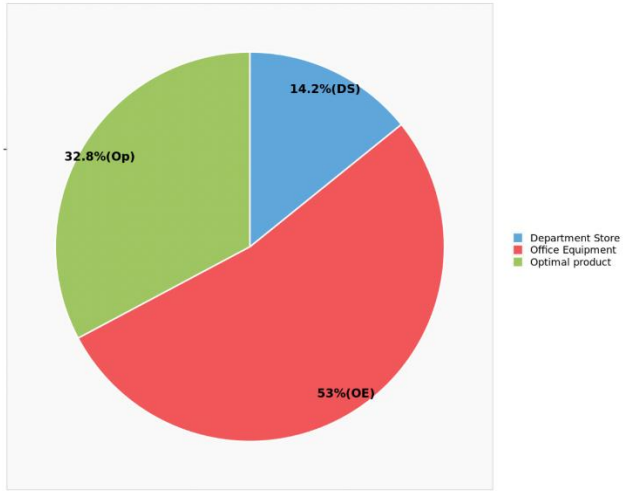

**Pareto frontier**. Non-dominated products (in terms of market shares and weighted revenue) are in red, dominated products are in gray, and the red line represents the Pareto frontier.

| | Office Equipment | Department Store | Optimal product | Revenue per unit | Weighted revenue |
|---|---|---|---|---|---|
| **Base predictions** | 78.8% | 21.2% | N/A | N/A | N/A |
| **...with optimal product 1** | 53.0% | 14.2% | 32.8% | $ 160.0 | $ 52.4 |
| **...with optimal product 2** | 47.3% | 13.0% | 39.7% | $ 130.0 | $ 51.6 |
| **...with optimal product 3** | 45.4% | 12.3% | 42.3% | $ 115.0 | $ 48.6 |

**Simulation results**. Predicted market shares, revenue per unit, and weighted revenue (i.e., revenue per unit multiplied by predicted market shares) for each optimal product.

The above tables show that optimal product 1, located is a store within 5 to 10 miles, having a large assortment of office supplies, no furniture, and offering software and computers. It is expected to garner 32.8% of the market whereas market shares for Office Equipment and Department Store would drop to 53.0% and 14.2% respectively.

The report produced will also show a pie chart of the market shares, when each optimal product is introduced.




**Predicted market shares ...with optimal product 1.**

Technical Appendix (Description of Hierarchical Bayes Choice Based Conjoint (CBC))

The first level of the hierarchy:

Let the distribution of partworths in a target population be specified as a multivariate Normal with mean $\boldsymbol{\mu}$ ($S \times 1$) and variance-covariance matrix H ($S \times S$).

$$\boldsymbol{\beta} \sim N(\boldsymbol{\mu}, \boldsymbol{H}) \;\; i = 1, 2, 3, \ldots n \qquad (1)$$

Each respondent's partworths, $\boldsymbol{\beta_i}$ ($S \times 1$), is drawn from this distribution.

The second level of the hierarchy:

For a given $\beta_i$ drawn from $\boldsymbol{N(\mu, H)}$ and for a given set of characteristics of alternative *j* included in a choice set *c*, denoted by $\boldsymbol{X_{jc}}$, let the utility of alternative *j* for respondent *i* be given by:

$$U_{ijc} = X_{jc}\beta_i + \varepsilon_{ijc}; \;\; j \in (1, 2, 3, \ldots J), c \in (1,2,..C) \qquad (2)$$

where $\boldsymbol{U_{ijc}}$ is utility for respondent *i* for alternative *j* in choice set *c*. $\boldsymbol{X_{jc}}$ is a (1 × *S*) vector of characteristics of the alternative *j*. Note that in choice-based conjoint, $\boldsymbol{X_{jc}}$ is not indexed by *i* because the alternatives have the same set of characteristics across respondents. Even though we have indexed $\boldsymbol{X_{jc}}$ by *c*, $\boldsymbol{X_{jc}}$ does not depend on *c*, i.e., the characteristics of an alternative are the same regardless of the choice set(s) to which an alternative may belong. Optionally, we can have different choice sets for every respondent, but for simplicity of notation we omit such an option in this exposition. $\boldsymbol{\varepsilon_{ijc}}$ has an *iid* extreme value distribution. This means that $\boldsymbol{U_{ijc}}$ is independent across respondents, and across choice sets for the same respondent (i.e., a respondent would realize the same relative utilities for the alternatives and make the same choices in a choice set, even if the choice sets were presented in a different order). Finally, the relative utilities of alternatives are independent across choice sets, a property known as IIA (Independence of Irrelevant Alternatives).

Under these assumptions, we can compute the probability that respondent *i* chooses alternative $\boldsymbol{j'}$ from choice set *c* as:

$$p_{ij'c} = \frac{e^{X_{j'c}\beta_i}}{\sum_{j \in c} e^{X_{jc}\beta_i}} \qquad (3)$$

For any given set of choices $\boldsymbol{j'}$ made by *N* respondents (i.e., one of the options will be selected by each respondent, while rejecting the other options), the Hierarchical Bayes model estimates $\boldsymbol{\hat{\mu}, \hat{H}, \text{and } \hat{\beta}_i}$ by maximizing the following likelihood function.

$$L = \sum_{i=1}^{N} \sum_{c=1}^{C} \sum_{j=1}^{J} y_{ijc} Ln(p_{ijc}) \qquad (4)$$

$\boldsymbol{y_{ijc}}$ = 1 if $j = \boldsymbol{j'}$ for individual *i* in each choice set *c*, and $\boldsymbol{y_{ijc}}$ = 0 otherwise.

Implementation of the above model within Enginius

We implement the above procedure by adapting the R-code described in Chapman and Feit (2019).

The option for respondents to select "None of these" is implemented by treating it just as another alternative available in each choice set and treating "None" as the base alternative for computing partworths. For estimating the utility of the "None" option, the model includes a constant term, but the values of all the other independent variables are set to 0. If a large proportion of respondents choose "None," then the constant term will likely have a large positive value. If very few respondents choose "None", then the utility of "None" option will be low (perhaps a large negative number).

The values of the vector $\boldsymbol{\mu}$ and matrix $\boldsymbol{H}$ are specified as diffuse priors for initiating the Hierarchical Bayes estimation. The software uses an iterative MCMC estimation routine, with a default value of 5,000 MCMC draws (burn-in and posterior), which can be changed by the user.

A few things to note about this modeling approach:

The accuracy of the estimation depends on the number of choices within a choice set (the fewer the better), the number of choice sets (the more the better), and the number of respondents in the study (the more the better).

We will get the same mean partworth estimates whether the data are from 100 respondents choosing from 10 choice sets or from 1,000 respondents each choosing from 1 choice set.

One disadvantage of including a "None" as one of the alternatives in choice sets is that it may lead respondents to avoid difficult choices, which might reduce the validity of the estimated market shares of the alternatives.

Reference:

Chapman, Chris, and Elea McDonnell Feit (2019). *R for Marketing Research and Analytics*, 2nd ed. Chapter 13: Choice Modeling. New York: Springer.