

Sustainability and Consumer Choice: Clustering Attitudes in the Italian Furniture Market

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MICS

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Case Study – Furniture Industry

Goal: Identify which sustainability goals regarding "Made in Italy" furniture companies are considered most critical for consumers.

Methodology: Conducted a structured survey using a five-point Likert scale (1 = not important at all; 5 = very important). Collected $n = 405$ answers.

Key corporate objectives evaluated:

- Product quality and reliability
- Production efficiency
- Cost reduction
- Profitability
- Functionality and usability
- Social well-being (employees, consumers, communities)
- Resource use efficiency
- Waste and emissions reduction
- End-of-life product management



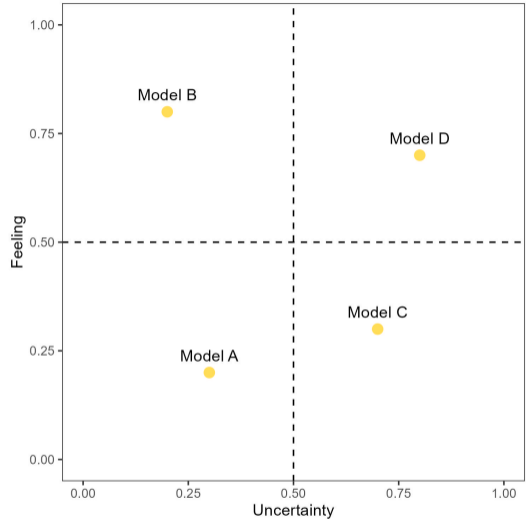
The CUB Model

Final Rating

It is modelled by a **C**ombination of a discrete **U**niform and a shifted **B**inomial distribution:

$$P(R = r \mid \xi, \pi) = \underbrace{\pi \binom{m-1}{r-1} (1-\xi)^{r-1} \xi^{m-r}}_{\text{Feeling}} + \underbrace{(1-\pi) \frac{1}{m}}_{\text{Uncertainty}}$$

with $\pi \in (0, 1]$ and $\xi \in [0, 1]$.





The MLC-CUB Model

For clustering rating data, we proposed a Mixture of Multivariate CUB Models, that we called **Multivariate Latent Class CUB** Model:

$$P(\mathbf{R} = \mathbf{r} \mid \boldsymbol{\pi}, \boldsymbol{\xi}, \boldsymbol{\omega}) = \sum_{k=1}^K \omega_k \prod_{j=1}^J \left[\pi_{jk} P_B(\xi_{jk}) + (1 - \pi_{jk}) P_U(m_j) \right],$$

where:

- K is the number of clusters;
- J is the number of ordinal variables;
- $\boldsymbol{\pi} = (\pi_{jk})$ is the $J \times K$ matrix of the uncertainty parameters;
- $\boldsymbol{\xi} = (\xi_{jk})$ is the $J \times K$ matrix of the feeling parameters;
- $\boldsymbol{\omega} = (\omega_k)$ is the vector of the mixing proportions



Maximum Likelihood Estimation

The estimation of the parameters is performed via Expectation-Maximization algorithm.
The complete Log-Likelihood is:

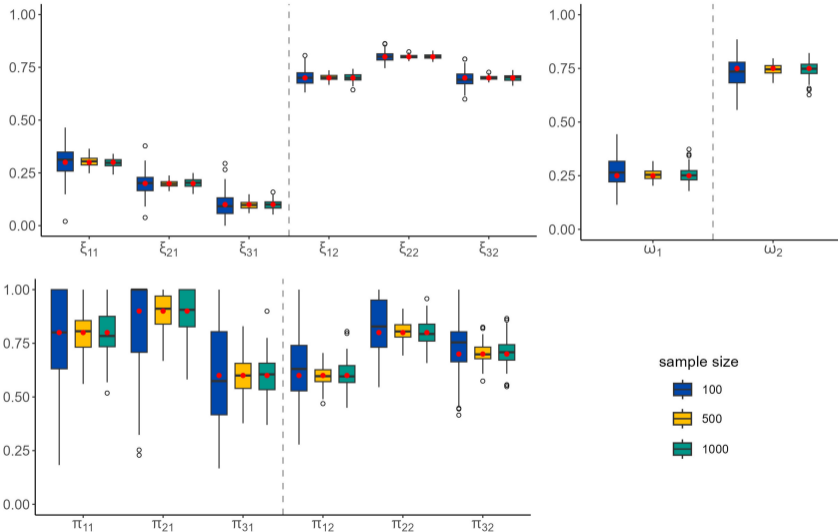
$$\begin{aligned} \ell_c(\boldsymbol{\xi}, \boldsymbol{\pi}, \boldsymbol{\omega} \mid \mathbf{R}, \mathbf{Z}, \mathbf{V}) = & \sum_{i=1}^n \sum_{k=1}^K z_{ik} \left\{ \ln(\omega_k) + \sum_{j=1}^J v_{ij} [\ln(\pi_{jk}) + \ln [P_{SB}(r_{ij} \mid \xi_{jk})]] + \right. \\ & \left. + \sum_{j=1}^J (1 - v_{ij}) [\ln(1 - \pi_{jk}) + \ln P_U(m_j)] \right\}. \end{aligned}$$

where

- \mathbf{R} is the matrix of the observed data;
- \mathbf{Z} is an indicator variable such that $z_{ik} = 1$ if the i th observation comes from cluster k , $z_{ik} = 0$ otherwise;
- \mathbf{V} is an indicator variable such that $v_{ij} = 1$ if, conditionally on \mathbf{Z} , the observation i comes from the shifted Binomial; $v_{ij} = 0$ if it comes from the Uniform.



Simulations - Goodness of the Estimates

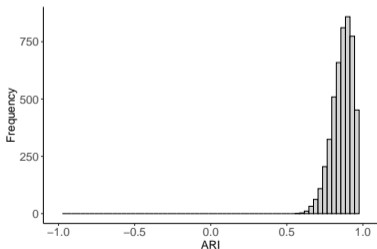




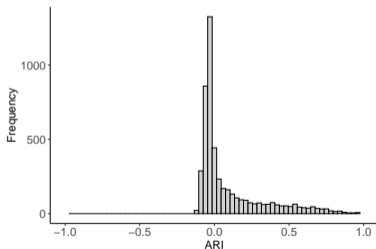
How to detect identifiability problems?

For detecting if in a real data set there are identifiability problems, we propose to:

1. perform the bootstrap of the original data set;
2. fit one model on each bootstrapped data set;
3. compare the classification obtained with the bootstrapped data sets with the original classification using the Adjusted Rand Index (ARI)



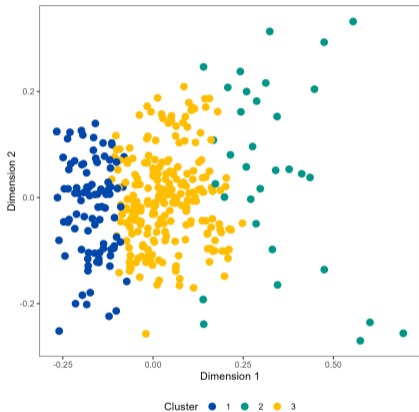
ARI distribution when the uncertainty is low



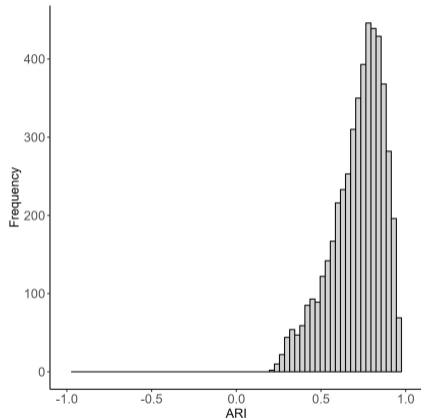
ARI distribution when the uncertainty is high



Case Study - The Clusters



Two-dimensional representation of the clusters obtained through multidimensional scaling (MDS).



ARI distribution



The Weighted Average Dissimilarity

A Weighted Average Dissimilarity (WAD) index, weighted by the size of the clusters, is proposed to assess the goodness of fit of the MLC-CUB Model:

$$WAD = \frac{1}{2J} \sum_{j=1}^J \sum_{k=1}^K \hat{\omega}_k \sum_{r=1}^m |fr(r_{jk}) - P(r_{jk} | \hat{\xi}_{jk}, \hat{\pi}_{jk})|,$$

where:

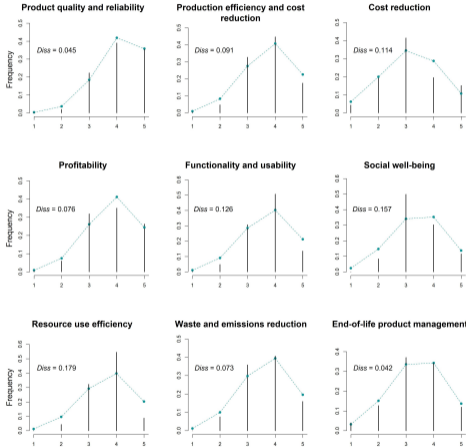
- $fr(r_{jk})$ is the observed frequency of rating r for variable j in cluster k ;
- $P(r_{jk})$ is the expected frequency of rating r for variable j in cluster k ;
- $\hat{\omega}_k$, $\hat{\xi}_{jk}$ and $\hat{\pi}_{jk}$ are the estimated parameters of the model.

The index takes values in $[0, 1]$:

- 0 means poor fit;
- 1 means perfect fit



Case Study - Goodness of Fit

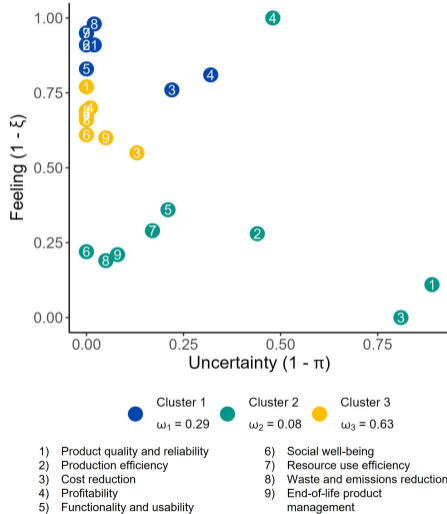


- Average *Diss* of cluster 1: 0.037
- Average *Diss* of cluster 2: 0.060
- Average *Diss* of cluster 3: 0.100
- Weighted Average *Diss*: 0.079

Observed and fitted frequencies item per item for cluster 3



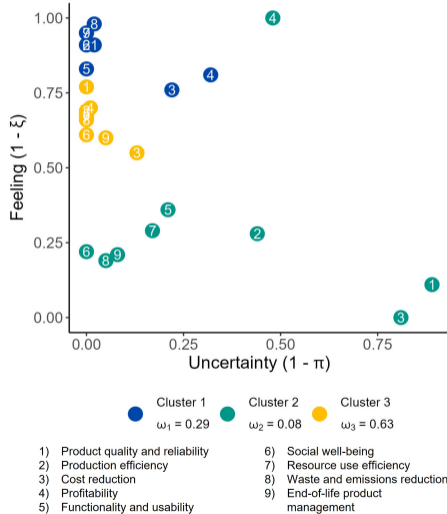
Case Study – Sustainability Advocates



Subjects in this cluster show high levels of feeling and low uncertainty across all items. Their responses reflect **strong emotional involvement** and **clear opinions**, especially on **sustainability-related goals** such as social well-being, environmental protection, and resource efficiency.



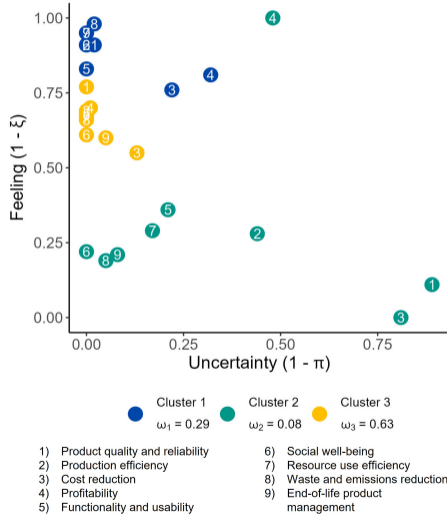
Case Study – Profit Skeptics



This group is characterized by low levels of feeling and high uncertainty, particularly regarding **economic objectives** like improving product quality and reducing costs. Their responses suggest **limited emotional engagement** and **hesitation** toward most of the proposed goals.



Case Study – Balanced Realists



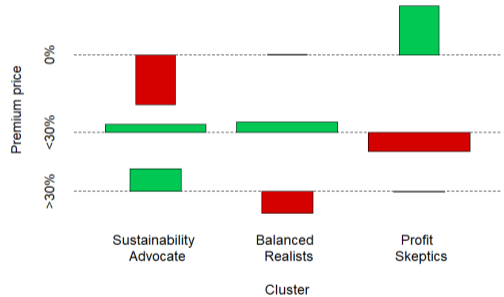
Subjects in this cluster show intermediate levels of feeling and very low uncertainty. They are most engaged with items related to **product quality and profitability**, while they express lower feeling toward **cost reduction**. Their answers indicate a **pragmatic and stable opinion**.



Case Study - Willingness to Pay

How much more would you be willing to pay for a furniture product that, while maintaining the same characteristics, also ensures a lower environmental impact?

- I would not be willing to pay any additional cost
- Up to 10% more
- Between 10% and 30% more
- Between 30% and 50% more
- More than 50% more



Association plot

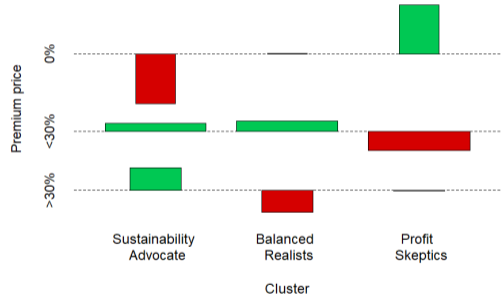


Case Study - Willingness to Pay

Each rectangle represents a cell of the contingency table:

- **Height:** standardized residual.
- **Width:** proportional to expected frequency.
- **Tall positive bars:** observed frequency is higher than expected.
- **Tall negative bars:** observed frequency is lower than expected.

The further the bar deviates from zero, the stronger its contribution to the association.



Association plot

Thank you for your attention!

For any questions, contact
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