Preference Mapping using Quantile Regression

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Introduction

- Understanding how consumers perceive food products is crucial for food companies.
- Food and beverages companies need information about which sensory characteristics drive consumer acceptance of goods.
- This information is used by marketing and R&D divisions to adapt existing products or create new products that meet consumers' expectation.

Preference mapping techniques are widely used to answer these questions.

Objectives

- One of the limitations of these techniques is that they focus on the *average effects* of sensory dimensions, as they are grounded on classical least squares regression (LSR).
- In Consumer Analysis it is also useful to study the whole distribution of consumers' liking.
- Quantile Regression (QR) can be used to provide an estimate of conditional quantiles of the liking instead of conditional mean [1] [2].

Aim

Extend the use of Quantile Regression to Preference Mapping to provide additional information about how the sensory dimensions link to consumer preference beyond the average.

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[1] Davino, C., Romano, R., Naes, T. (2015). The use of quantile regression in consumer studies. *Food Quality and Preference*, 40, 230-239.

[2] Davino C., Romano R., Vistocco, D. (2018) Modelling drivers of consumer liking handling consumer and product effects, (forthcoming).

Outline

1. Background
   - Preference Mapping
   - Quantile Regression
2. The proposal
3. The case study
   - Preference Mapping by Least Squares Regression
   - Preference Mapping by Quantile Regression
4. Conclusion

Background

Preference mapping

There are two different types of methods, namely internal preference mapping (MDPREF) and external preference mapping (PREFMAP) [3]:

- MDPREF uses consumer acceptance ratings to determine a multidimensional representation of products and consumers in a common space.
- PREFMAP uses sensory descriptive attribute ratings to obtain a multidimensional representation of products, sensory characteristics and consumers in a common space.

	Sensory Descriptors				
p	x_{11}	:	:	:	x_{1K}
r	:	:	:	:	:
o	:	:	x_{ik}	:	:
d	:	:	:	:	:
u	:	:	:	:	:
c	:	:	:	:	:
t	x_{I1}	:	:	:	x_{IK}
s					

	Consumers' Liking				
p	y_{11}	:	:	:	y_{1J}
r	:	:	:	:	:
o	:	:	y_{ij}	:	:
d	:	:	:	:	:
u	:	:	:	:	:
c	:	:	:	:	:
t	y_{I1}	:	:	:	y_{IJ}
s					

[3] Meullenet J.F., Xiong R., Findlay C.J. (2008) *Multivariate and probabilistic analyses of sensory science problems*, John Wiley & Sons Ltd, United Kingdom.

External Preference Mapping by Least Squares Regression

A two step procedure that combines principal component analysis (PCA) and least squares regression (LSR) [4]:

step1 A a perceptual map of the products is obtained through a PCA of the product-by-attribute sensory matrix:

$$X = TP' + E$$

the T Principal Components (PC's) are called key sensory dimensions[5].

step2 A regression model is used to fit each consumer in the perceptual space:

$$y_{ij} = \beta_{j1} t_{i1} + \beta_{j2} t_{i2} + \epsilon_{ij}$$

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[4] Naes T., Brockhoff P.B., Tomic, O. (2010) *Statistics for Sensory and Consumer Science*, John Wiley & Sons Ltd, United Kingdom.

[5] Meilgaard M.C., Carr B.T., Civille G.V. (1999) *Sensory evaluation techniques*, CRC press, Boca Raton.

Quantile Regression

QR [6] [7] can be considered an extension of conditional mean models to the whole conditional distribution of the response variable:

$$Q_\theta(\hat{\mathbf{y}}|\mathbf{X}) = \mathbf{X}\hat{\beta}(\theta)$$

- $Q_\theta(.|.)$ is the conditional quantile function for the θ-th quantile.
- θ is a given conditional quantile, with $0 < \theta < 1$.

Estimates in QR follows the classical interpretation:

Each $\hat{\beta}(\theta)$ coefficient represents the rate of change in the θ-th conditional quantile of the dependent variable per unit change in the value of the j-th regressor ($j = 1, \ldots, p$), holding the others constant.

[6] Koenker, R., Bassett Jr, G. (1978). Regression quantiles. *Econometrica*, 46, 33-50.

[7] Davino, C., Furno, M., Vistocco, D. (2013). *Quantile regression: theory and applications*. Wiley.

The proposal

External Preference Mapping by Quantile Regression

QR is introduced in the second step of the PREFMAP, i.e. when liking for each consumer is related to the first sensory dimensions:

$$y_{ij}(\theta) = \beta_{j1}(\theta)t_{i1} + \beta_{j2}(\theta)t_{i2} + \epsilon_{ij}$$

where $(0 < \theta < 1)$.

Two different perspectives

1. Results whit respect to each consumer.
2. Results with respect to the whole panel of consumers.

External Preference Mapping by Quantile Regression

1. Results whit respect to each consumer

- The introduction of QR in PREFMAP provides a set of coefficients for each quantile of interest.
- This information allows to measure what is the impact of a change in the sensory dimensions on the liking for the most and least preferred products.

2. Results with respect to the whole panel of consumers

- QR allows to obtain several consumer loading plots ($0 < \theta < 1$) that visualizes groups of consumers who are similarly affected by a given change on the sensory dimensions.
- It is also suggested a conjoint representation able to simultaneously represent results related to two opposite quantiles (e.g $\theta = 0.25$ and $\theta = 0.75$).

The case study

Data description

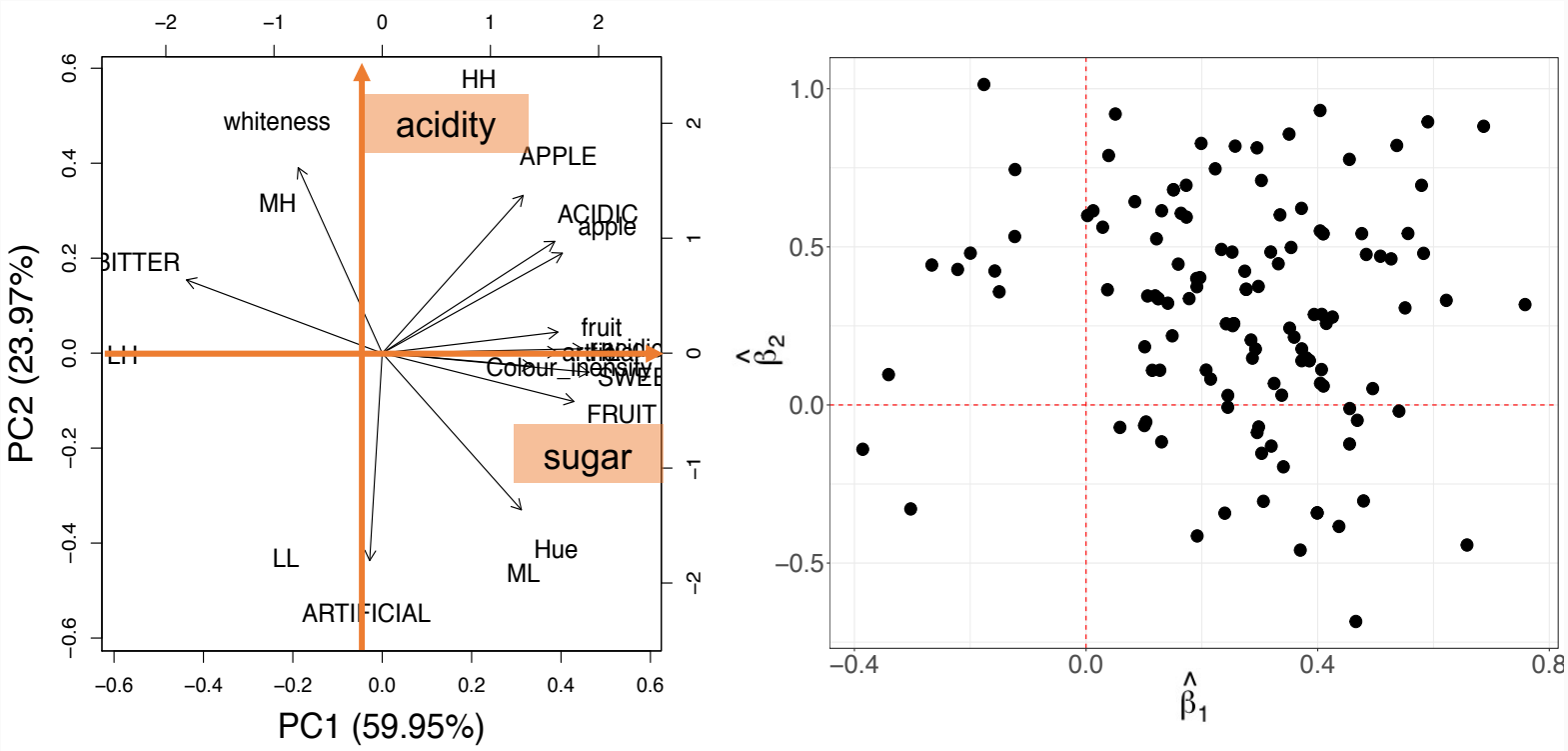
Data have been obtained from the article by Rødbotten *et al.* (2009) [8]:

- Apple juice samples were selected according to an experimental design (a 2*3 factorial design) with two levels of acid concentration (H=high, L=low) and three levels of sugar concentration (H=high, M=medium, L=low).
- The 6 samples were tested by 125 consumers using the 9-point hedonic scale [9].
- Descriptive sensory analysis: each product was described by 13 descriptors related to *flavor* and *odor*.

[8] Rødbotten M., Martinsen B.K., Borge G.I., Mortvedt H.S., Knutsen S.H., Lea P., Naes T. (2009) A cross-cultural study of preference for apple juice with different sugar and acid contents, *Food quality and preference*, 20(3), 277-284.

[9] Peryam D.R., Pilgrim, F.J. (1957) Hedonic scale method of measuring food preferences, *Food technology*, 11(9), 9-14.

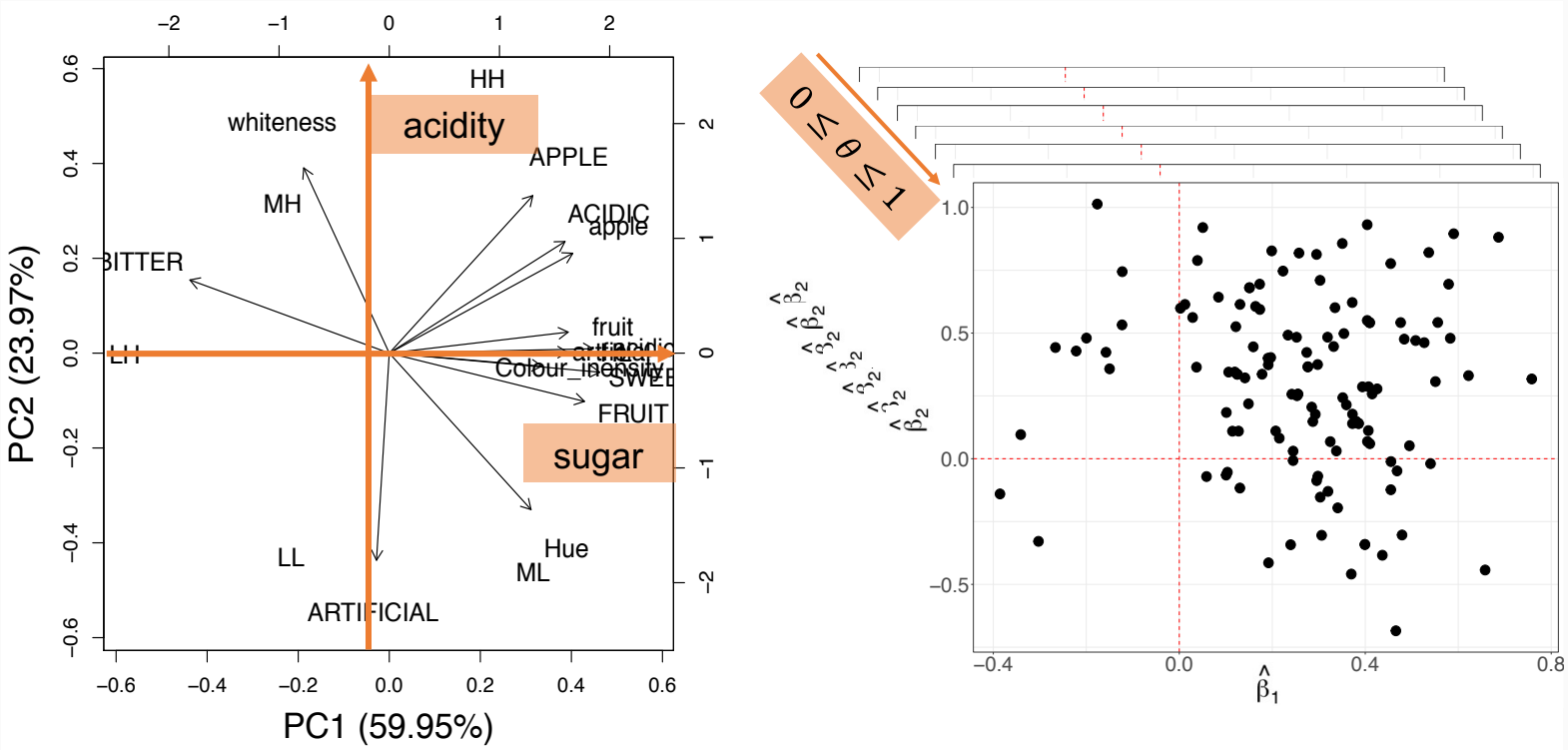
Preference Mapping by classical LSR



Almost all consumers prefer sweet products, but some of them prefer products with high acid content, while the others prefer a low acid content [a].

[a] The first letter indicates sugar level (L: low, M: medium, and H: high) and the second letter the acid level (L: low and H: high).

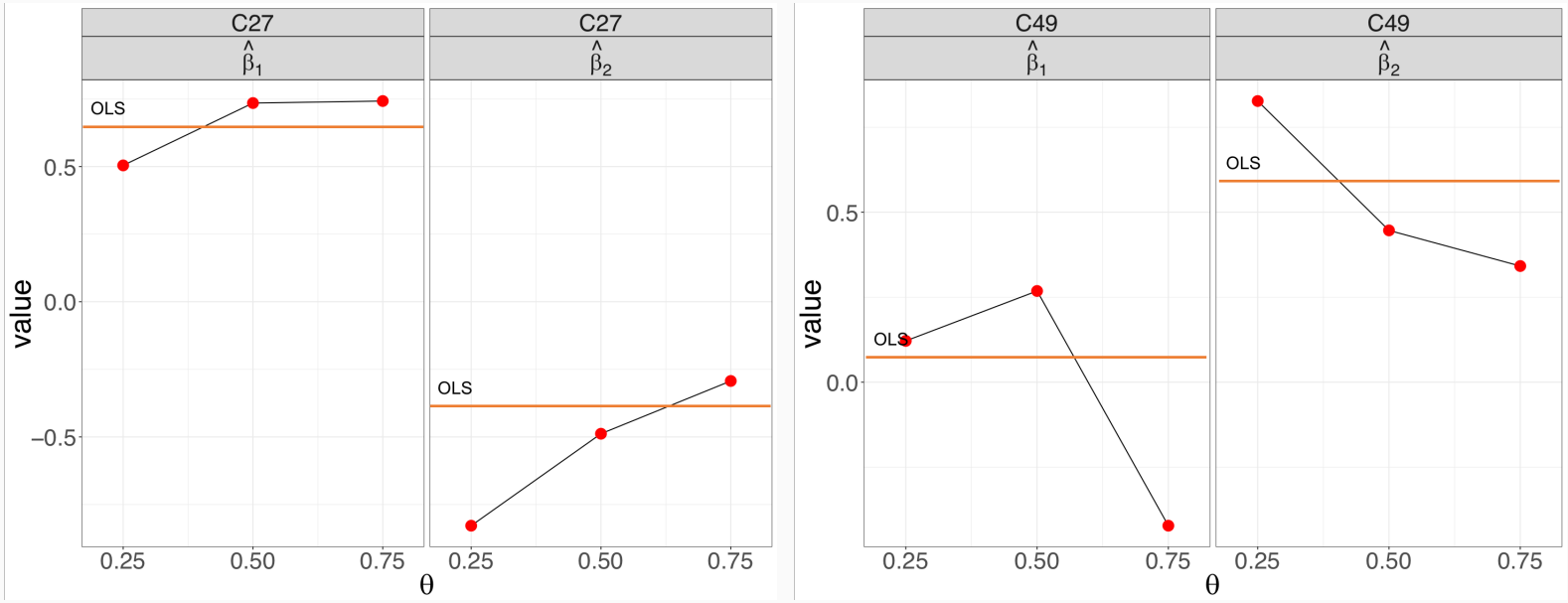
QR results for single quantiles



- It is potentially possible to estimate an infinite number of loading plots, but in practice a finite number is numerically distinct (quantile process).
- In practice, it is quite common that each researcher defines the quantiles of interest which, in most cases, are the three quartiles.
- We propose a conjoint representation able to simultaneously represent results related to two opposite quantiles ($\theta = 0.25$ and $\theta = 0.75$).

QR results for single consumers

Consider estimating a QR model for each individual consumer and for a set of quantiles of interest ($\theta = [0.25, 0.5, 0.75]$).

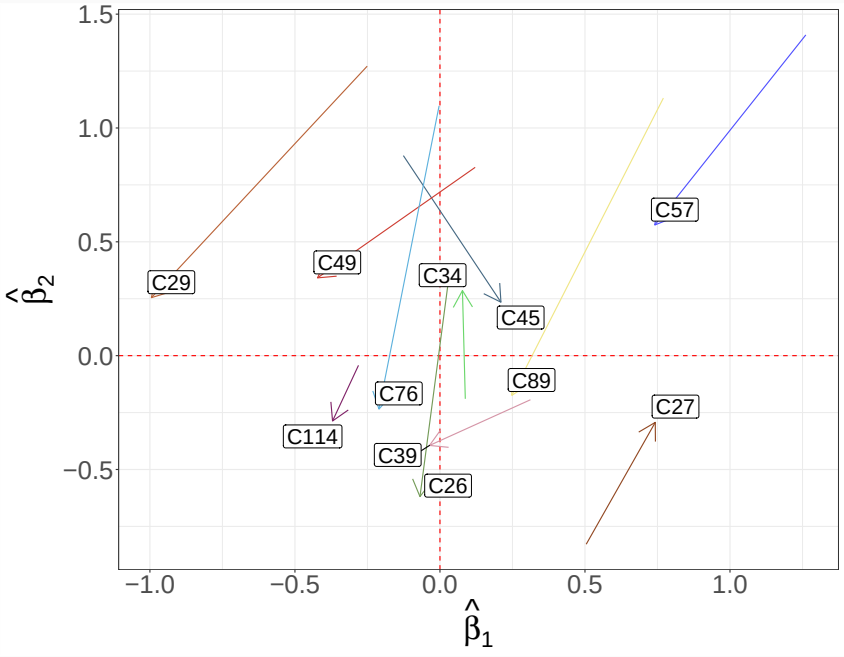


- The coefficients β_1 are always higher than coefficients β_2 that are even negative.
- The effect of the predictors on the conditioned upper part of the liking distribution is stronger.

- The sensory dimensions have different size and sign on the different quantiles.
- An increase in the level of sweetness (PC1) would increase the preference for the less preferred products and reduce that for the most preferred ones.

QR for the whole panel

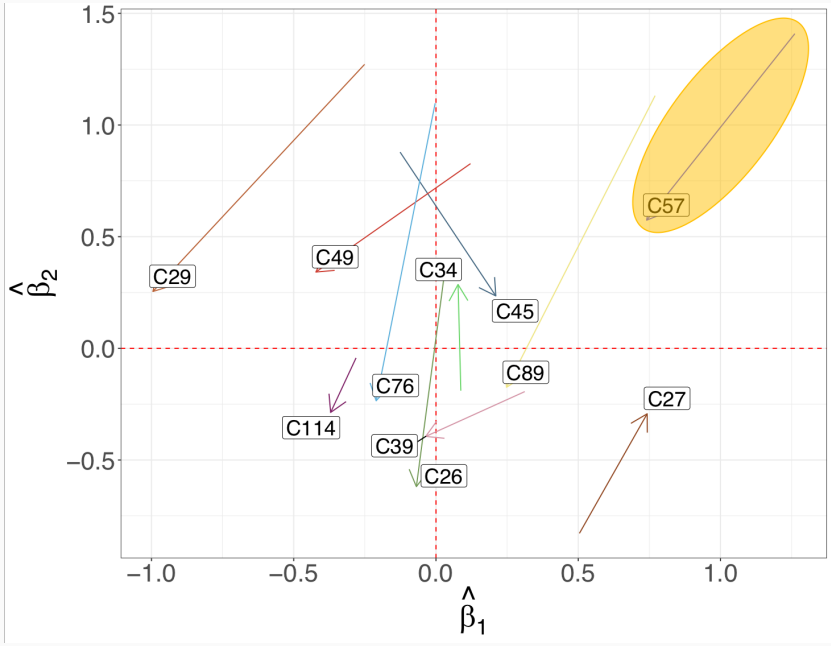
PREFMAP suggests possible drivers to increase the liking but whatever action will have different impacts on different consumers.

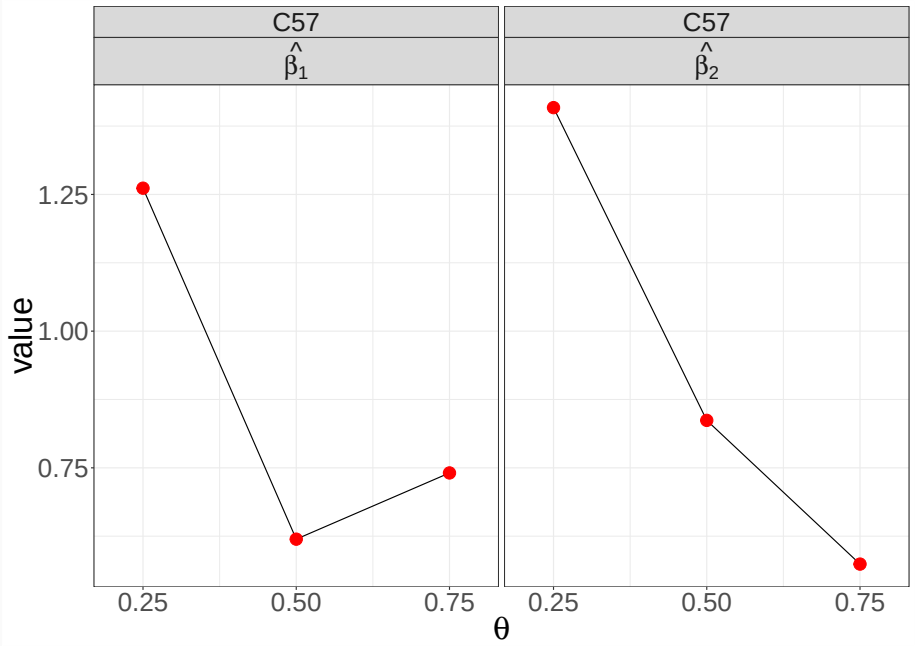


- each consumer is represented according to the β_1 and β_2 coefficients estimated at the two quantiles ($\theta = 0.25$, $\theta = 0.75$.).
- the two points representing each consumers are linked by an arrow depicted in the direction from $\theta = 0.25$ to $\theta = 0.75$.
- arrows crossing two quadrants represent consumers with non-concordant signs at $\theta = 0.25$ and $\theta = 0.75$.
- consumers able to discriminate preferences among products are represented by a longer arrow.

QR for the whole panel

PREFMAP suggests possible drivers to increase the liking but whatever action will have different impacts on different consumers.

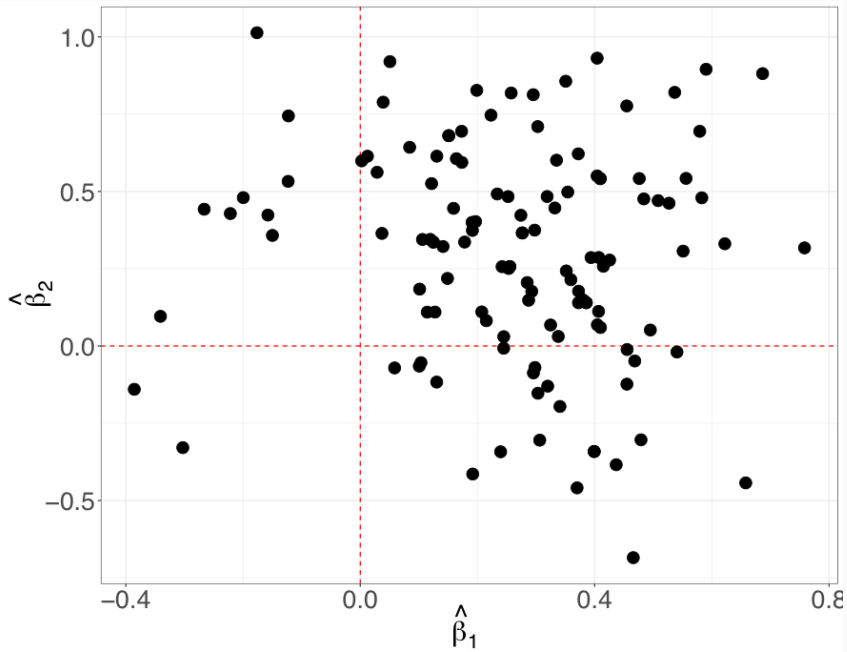


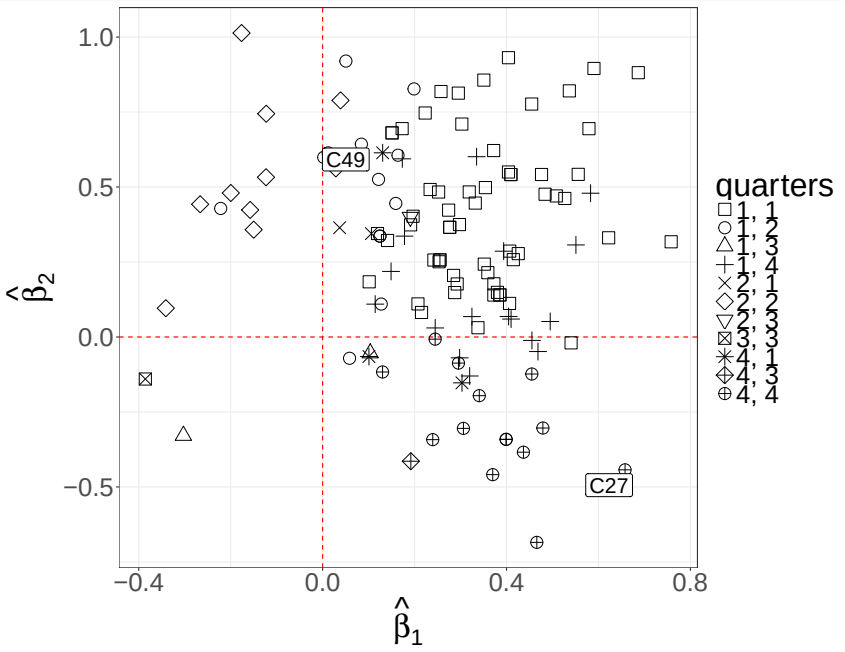


For C57 both coefficients related to PC1 and PC2 are positive but any action on the variables correlated to them will have a higher impact on the liking of the less preferred products.

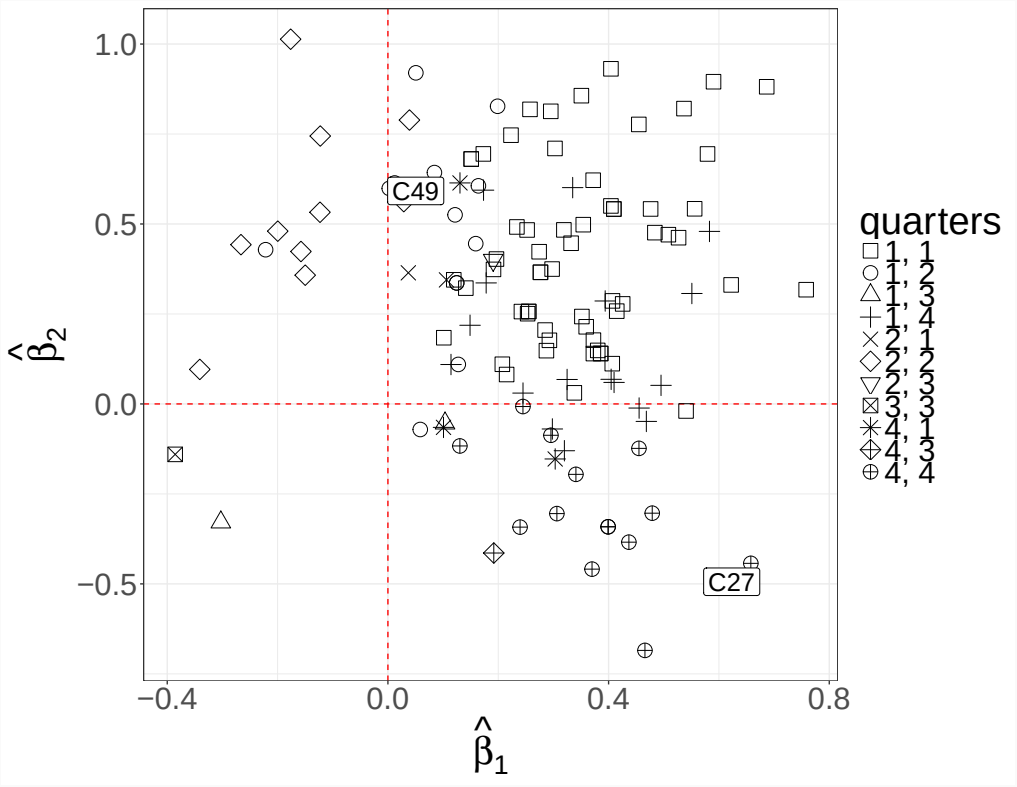
QR for the whole panel

A plot combining results of LSR and QR approach to PREFMAP.





QR for the whole panel



- The different symbols correspond to all the different possible directions for the arrows in the previous plot.
- The symbols corresponding to two equal numbers indicate consumers who are located in the same quadrant since coefficients of the two quantiles with respect to the two components have the same signs.

The plot allows to visualize the variability of preferences with respect to preference directions

⇓

if we considering the direction of maximum preference, i.e. consumers in the first quadrant, not all of them have coefficients consistent with the different quantiles.

Conclusion

Conclusions

Recap:

- Estimation of the whole distribution of consumer preference.
- Additional information at the individual consumer level, analyzing how the preference varies with respect to the different quantiles.
- Additional information at the general level, highlighting on the preference map consumers with homogeneous behaviors with respect to the different quantiles.

Future avenues:

- Introduction of a "risk" assessment measure: how much information on the extreme quantiles is different from the average effect.
- Exploring model assessment tools.

THANK YOU FOR YOUR ATTENTION!

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