RTG 1644
Scaling Problems in Statistics

Heterogeneity in price changes in the German butter market

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Poster presented at the 55th GEWISOLA annual Conference Gießen, 23.-25. September 2015

1. Motivation

Scaling problems are omnipresent in many areas of applied research. In vertical price transmission (VPT) the characteristics of the observed prices processes depend significantly on whether individual observations are studied or whether these observation are aggregated to averages.

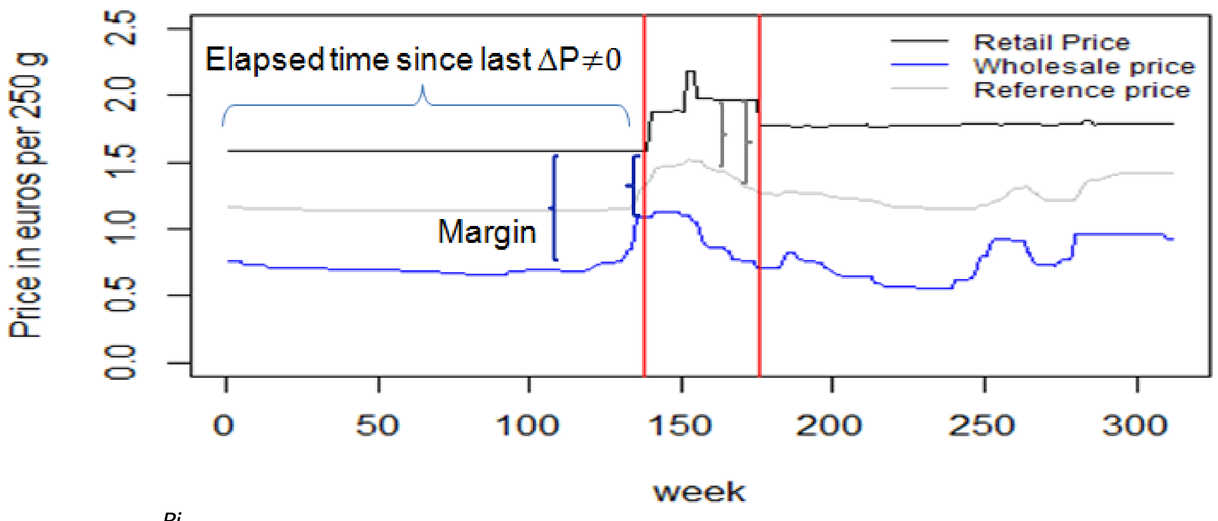
The effect of scale on the measurement of VPT has been to some extent ignored in the design of methods and the research questions in the literature.

The hierarchically structured data where aggregation or disaggregation on different levels of the hierarchy of the supply chain (e.g., Product, Store and Chain) might affect the statistical analysis and the conclusions which we draw from the VPT analyses.

2. The research gap

Scaling problems : the units under statistical investigation are likely to behave very differently when studied on different scales.

What determine the price changes at the smallest possible scale (i.e. the individual store) ?



$$Pr(\Delta Price_t^{Ri} \neq 0) = f(margin, Elapsed\ time,\ reference\ price, control\ \ variables,\ unobserved\ heterogeneity)$$

Two Scenarios:

First : if the wholesale prices are increasing, the margin becomes smaller, therefore there is a tension between the need to change the retailer's "regular" price and the costs (i.e. Menus costs") underlying any change in this regular price. The elapsed time since the last change in regular price has been made influences the likelihood that a retailer will introduce again a change in its regular price.

Second: if the wholesale prices are decreasing, the tension now comes not from the margin, which obviously increases, but from the level of the reference price of the other competing retailers.

4. Objectives

First: how changes in the price are determined and transmitted at the smallest possible scale (i.e., the disaggregated retail level).

Second: How can we take into account the hierarchical structure of the data (i.e., product-store-chain), as a typical example where scaling problems may occur, in order to explain the unobserved heterogeneity between the different chains?

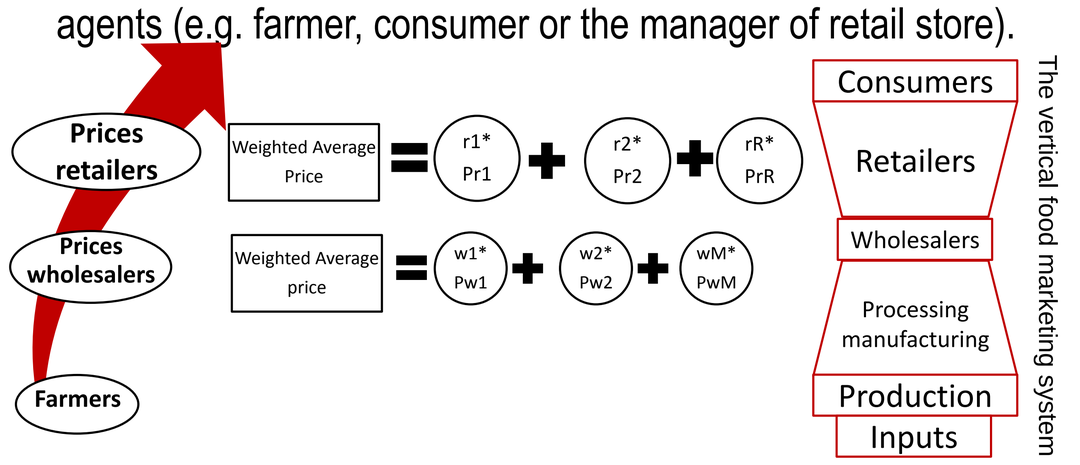
5. Hypotheses

First: The Chains which are sensitive to the changes in their margin will adjust more frequently their prices than the other Chains.

Second: The Chains which are sensitive to the changes in their Menu Costs will adjust less frequently their prices than the other Chains.

Third: The Chains which are flexible/rigid in terms of sitting their prices will deviate from the average margin and will be distributed in the tails.

In theory : VPT is explained with reference to individual economic agents (e.g. farmer, consumer or the manager of retail store).



In empirical applications: most studies employ aggregated data (e.g., average retail prices in a region or a country).

6. Data

Retail level: a balanced panel data on 1087 different EANs during 312 weeks of retail prices for 250 gram foil-wrapped packages of butter in Germany.

Wholesale level : weekly weighted average national price for butter that is quoted by the SBKB for the period 2005-2010.

7. Methods

GLMM : In a Generalized Linear Mixed Models framework, given the covariates and random effects γ, the conditional mean $\mu_{ij} = E(y_{ij} \mid \gamma)$ is linked to the linear predictor $\eta_{ij} = x_{ij}'\beta + u_{ij}'\gamma_i$ through the link function g: $\eta_{ij} = g(\mu_{ij})$.

$$Pr(\Delta Price_{ijpsc}^{Retail} \neq 0) = logit^{-1}(\beta^0 + \beta^{margin} margin_{i[j]} + \sum_k^K covariate_{k[ij]} + \sum_l^L \beta^l control_{l[i]} + \sum_m^M \beta^m control_{m[ij]} + \gamma_i^{margin} margin + \gamma_c^{margin} margin + \gamma_i + \gamma_p + \gamma_s + \gamma_c)$$

$$\gamma_i \sim N(0, \sigma_i^2),\ for\ i = 1,...,1087;\ \gamma_p \sim N(0, \sigma_p^2),\ p = 1,...,56;\ \gamma_s \sim N(0, \sigma_s^2),\ s = 1,...,345;$$

$$\gamma_c \sim N(0, \sigma_c^2),\ c = 1,...,37;\ \gamma_i^{margin} \sim N(0, \sigma_{i[margin]}^2);\ \gamma_c^{margin} \sim N(0, \sigma_{c[margin]}^2)$$

8. Results and discussion

Fixed Effects

Fixed Effects	Estimate	95% Confidence	interval	Expected Sign	Obtained Sig
Covariates					
Intercept	1.002	0.513	1.492	?	+
Elapsed time since last $\Delta Price \neq 0$	-0.126	-0.129	-0.124	+	-
Margin	-3.237	-3.689	-2.845	-	-
Reference price	1.234	0.988	1.479	+	+
Control Variables					
Promotional price	1.490	1.458	1.522	+	+
Display	0.394	0.263	0.525	+	+
Communicative Support	1.486	1.411	1.561	+	+
Private Label	-0.815	-1.351	-0.278	-	-
Supermarket	0.338	0.072	0.604	+	+
Hypermarket	0.338	0.085	0592	+	+

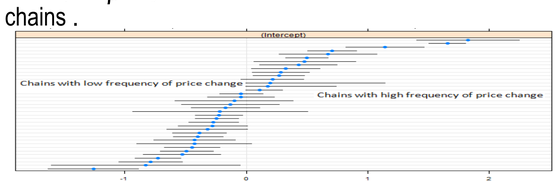
Interpretation: in GLMM a correct interpretation in terms of odds ratio of the fixed effects require that we stay in the same chain or chains with the same random effects, we only look at the signs of the estimates.

Unexpected sign: the sign of the Elapsed time since the last price change. It might be the case that threshold effects are involved, i.e., some chains change prices infrequently until they get to a certain elapsed time.

Random Effects

Random Effects	Item	Product	Store	Chain
Number	1087	56	345	37
Variance	$\sigma_i^2 = 0.127$	$\sigma_p^2 = 0.315$	$\sigma_s^2 = 0.017$	$\sigma_c^2 = 0.437$

Random intercept: most of the deviations from the intercept are explained by the differences between the 37 different chains .



Random slope : most of the deviations from the fixed effect estimate of the margin are explained by the differences between the 1087 items. The grouping variable chains also explain the deviations average slope β^{margin} .

Random Effects	Item	Product	Store	Chain
Number	1087	56	345	37
Intercept	$\sigma_i^2 = 0.737$	$\sigma_p^2 = 0.165$	-	$\sigma_c^2 = 0.169$
Margin	$\sigma_{i[margin]}^2 = 3.855$	-	-	$\sigma 2_{c[margin]} = 1.258$

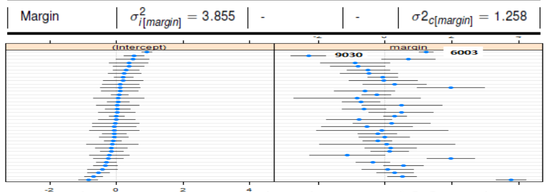


Illustration : the chain with an id="6003" has an average duration between two price changes of 2.2 weeks, an increase of 1% in the average margin implies a decrease in its likelihood of introducing a price change of 1.1%. Whereas for the chain with an id="9030" which has an average duration between two price changes of 8.7 weeks, an increase of 1% in the average margin implies a decrease in the likelihood of changing price of 38%.

9. Conclusion:

our study use hierarchically structured data. It is a common case where scaling problems may occur. We use mixed models in order to gain consistent results. We raise the awareness of the scaling problems and their importance in the design of research methodology.

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Abbreviations :
SBKB: Süddeutsche Butter- und Käse-Börse – South German Butter and Cheese Exchange
EAN: European Article Number