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Demand for carbon-neutral food –
evidence from a Discrete Choice Experiment for milk and apple juice

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Abstract

To internalize climate-related external costs from agricultural production and food consumption Pigou taxes and carbon credits increase private costs for food. Voluntary consumer choices for carbon-neutral food can be advantageous over such policy measures since they avoid higher food prices for the poor. We empirically analyze consumers' willingness-to-pay for hypothetical carbon-reduced as well as carbon-neutral milk and apple juice. Data are collected in Discrete Choice Experiments in a German supermarket. Estimates reveal a substantial price premium for the carbon-neutral products which is probably sufficient to cover the products' extra costs, including the purchase of carbon credits. The premiums are around 0.20 € per liter milk and 0.30 € per liter apple juice. Although the external validity of stated-preference methods is limited the willingness-to-pay measures for organic milk and juice as well as for different real-world labels in our experiment are similar to real-world price premiums.

Keywords: climate change, carbon-neutral food, discrete-choice-experiment

JEL code: Q54, Q130, Q180

1. Introduction

Agriculture and food consumption cause 10 to 12% of global greenhouse gas emissions (Intergovernmental Panel on Climate Change, Smith *et al.* 2007). As an example, the carbon footprint of one liter milk amounts up to 1.4 kg carbon dioxide equivalent (e.g. Thomassen *et al.* 2008) which is more than from burning half a liter of gasoline. Economists might think of different first-best policies to internalize this external effect into either production or consumption of food. Common theoretical suggestions in the climate change discussion are either Pigou taxes for production in greenhouse gas relevant industries or including these industries in carbon credit trading systems. Concerning the food sector, a Pigou tax would increase marginal costs of food production by pricing the production related emissions (or a proxy for the emissions). In a carbon credit system a producer's carbon credits determine the maximum greenhouse-gas emissions which may be emitted by the producer. Since the producer must buy or can sell credits they get a value for him and, thus, the emissions are priced in his production. In other words, like Pigou taxes carbon credits increase the (private) marginal costs of food production. Consequently, both policies – Pigou taxes and carbon credits – would probably increase global food prices.

Unfortunately, higher food prices would aggravate global hunger as we have learned from the latest global food crisis. Thus, globally higher food prices to reduce global greenhouse gas emissions would probably come at ethically unacceptable costs – more hunger in the world. In addition, negative side-effects of such policies may occur not only in poor countries because low food prices are a political objective in rich countries, too. Instead of political measures we analyze a private and voluntary approach to internalize at least some of the food related greenhouse gas emissions without increasing global food prices. In addition to common food products carbon-reduced or even carbon-neutral food can be offered in a new market segment. The latter products have higher costs, but it is each consumer's free choice to buy common food or to pay more for carbon-neutral food.

Carbon-neutral food products are rare today. Some examples, including wine, juice, mineral water and coffee brands offered in Australia can be found on the internet (Carbon Reduction Institute, 2011). The UK based supermarket company Tesco operates three "zero-carbon stores" in the UK, the Czech Republic, and Thailand (Tesco 2011). The fruit company Dole wants to "establish a carbon neutral product supply chain for bananas and pineapples" (Dole 2011). There is probably a bundle of reasons why carbon-neutral food products are not yet commonly launched to markets. Among, these the new products cause costs in terms of buying carbon credits to offset the products' carbon footprint and they will cause common set-up costs for establishing new products. Unfortunately, to our best knowledge estimates on consumer demand for these products are not yet available. Consequently, food companies and retailers can hardly assess the profit potential and loss risk of launching carbon-neutral food.

We want to contribute to fill this gap by empirically investigating consumers' willingness to pay for milk and apple juice with different carbon footprints. In a Discrete Choice Experiment we ask consumers to choose their most preferred milk and juice from a set of different hypothetical alternatives. Based on multinomial probit and random-parameters multinomial logit models we, then, estimate consumers' willingness-to-pay for reducing the carbon footprint of milk and apple juice. The paper's next section describes the choice experiment and sets out the conceptual and empirical model. Then we present the results before we discuss them and before we offer conclusions in the paper's final section.

2. Methodology

To quantify consumers' willingness-to-pay for carbon-reduced and carbon-neutral beverages we conducted Discrete Choice Experiments with consumers in Germany. We chose milk and apple juice as products. Milk has a high carbon footprint per liter compared to other beverages. Apple juice was chosen for comparison purposes. For the survey we asked consumers in a large supermarket in the 240,000-inhabitant city of Kiel which is the capital of the northernmost German *Bundesland* (= federal state) *Schleswig-Holstein* in March 2010. The questionnaire contained information about the carbon-footprint of milk and apple juice, a comparison with the carbon-footprint of car driving, some questions about consumers' food purchase behavior, the discrete choice experiment with milk and apple juice, and, finally, questions about some socio-economic characteristics of the respondent.

The Choice sets

The core of a Discrete Choice Experiment are the so-called choice sets. Each choice set in our questionnaire consisted of three milk or apple juice alternatives. Respondents were asked to choose their most preferred option. Table 1 exemplifies a choice set for milk. Each alternative was characterized by its brand, carbon-footprint per liter beverage, local product measured by distance between production and point of sale, organic or conventional production, and price in € per liter. The different labels for milk and apple juice had been actually sold in the supermarket. One brand is a retailer's label, one is a regional label and the third is a national premium label. The three brands have been assigned randomly to the left, middle, or right alternative in each choice set.

Table 1. Choice set for milk

carbon footprint (kg CO_2 per liter)	2 kg	0 kg	2 kg
distance between farm and diary and supermarket	250 km	250 km	50 km
organic production	organic	conventional	conventional
price (€ / Liter)	0,59 € / liter	0,89 € / liter	0,39 € / liter
Mark your most preferred choice, please	O	O	O

Table 2 summarizes the attribute levels applied for both beverages in the choice experiments. We had three different levels for the carbon footprint. The maximum was above or close to maximum literature estimates, the minimum level was carbon-neutrality, of course. For milk see e.g. Thomassen *et al.* (2008) while the apple juice values are from the Austrian scientific project *futuro* (www.futuro-preise.at). The locality measure for production was varied with 50 km, 250 km as well as 500 km. For the third attribute, we had organic and conventional farm production. The price was varied in five identical steps from 0.39 € per liter to 0.89 € per liter for milk and 0.39 € per liter to 1.39 € per liter for apple juice.

Table 2. Attribute levels for milk and apple juice choice sets

attributes	**MILK**	**APPLE JUICE**
carbon footprint	0, 1, 2 kg CO_2 per liter milk	0, 0.2, 0.4 kg CO_2 per liter juice
distance between farm and diary (juice press) and supermarket	50, 250, 500 km	50, 250, 500 km
organic production	organic, conventional	organic, conventional
price	0.39, 0.49, 0.59, 0.69, 0.79, 0.89 € per liter	0.39, 0.59, 0.79, 0.99, 1.19, 1.39 € per liter
brands	*Frischgold, Hansano, Bärenmarke*	*Wesergold, Becker's Bester, hohes C*

From the attributes (except brand) follow 3x3x2x6 = 108 different alternatives which can be combined to a maximum of 108^3 = 1,259,712 different choice sets. Instead of this full factorial design we constructed a reduced orthogonal design by means of the software program SPSS. After canceling out two choice sets with probably dominant alternatives we used 79 different choice sets for both beverages. To ensure a realistic alternative for price-conscious consumers we ensured that each milk choice set contained a milk with a price of 0.49 € or 0.39 € per liter. To avoid dominant alternatives in these cases, we switched some conventional milk alternatives to organic. Despite these adjustments the design was nearly perfectly orthogonal. The choice sets for both beverages differ only in the respective attribute values from table 2.

The Choice Model

Discrete Choice Models are a stated preference method and, thus, they are very common in analyzing demand for non-market products such as public goods or not yet launched products. Well published examples for such food product studies are e.g. Goldberg and Roosen (2007), Lusk *et al.* (2003). The description of Discrete Choice Models is textbook standard; we have adopted the following passage from Breustedt *et al.* (2008). Discrete Choice Models are based on Lancaster's characteristics theory of value implying that a product's utility for a consumer is the sum of the product characteristics' utilities. Following Ben-Akiva and Lerman (1994) we define a random utility function which consists of a deterministic (V_{ij}) and a stochastic (ε_{ij}) component:

(1) $$U_{ij} = V_{ij} + \varepsilon_{ij}$$

where U_{ij} is the ith consumer's utility of choosing product alternative j, V_{ij} is the systematic portion of the utility determined by the attribute levels of alternative j and consumer i's characteristics and ε_{ij} is the error term. The systematic portion of utility can be expressed as

(2) $$V_{ij} = \beta_1 x_{ij1} + \ldots + \beta_a x_{ija} + \beta_{j0} + \beta_{j1} x_{i1} + \ldots + \beta_{jm} x_{im}$$

where x_{ija} is the ath attribute of alternative j for consumer i, and x_{im} is the mth personal characteristic of consumer i, and the βs are the coefficients to be estimated. The constant β_{j0} can be alternative-specific. In our analysis, the βs do not vary for the same attribute for different alternatives, but they can vary, in principle, for the same personal characteristic for different alternatives.

Then it is assumed that the consumer chooses exactly one alternative among the choice set's J alternatives. By assumption, the consumer chooses his utility maximizing alternative. Since utility cannot be observed we turn to the probability that alternative j is chosen in preference to any alternative k by consumer i as per (3):

(3) $$\text{Prob}\left\{V_{ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik}; \text{for all } k \in \Omega_i\right\}$$

where Ω_i is the choice set for consumer *i*. In our case the choice sets consist of three different milk or apple juice brands.

The Estimation Approach

To estimate (3) an assumption for the distribution of the error terms ε is needed. A Gumbel distribution is convenient to assume since it allows for estimating a (multinomial) logit model. However, this model assumes the so-called independence of irrelevant alternatives (IIA) which is rejected for our datasets by means of a Hausman test (Hausman and McFadden, 1984). Consequently, we estimated a multinomial probit (MNP) and a mixed logit model (also called random-parameters or error-components logit) (MXL) which do not need to assume independent errors among alternatives which follow from the IIA assumption. Since the multinomial probit assumes a multivariate normal distribution of the errors terms it accounts for correlated errors among the alternatives. The mixed logit in contrast allows the parameter estimates for the attributes to be random ensuring independent error terms. Estimation procedures for the multinomial probit and the mixed logit model are e.g. implemented in the statistics software *stata*.

Despite their signs the estimated β_j are not very descriptive in both estimation procedures. A more descriptive measure is the marginal impact of one right hand side variable relative to the price' marginal impact. It then describes the monetary equivalent of changing the right hand side variable by one unit. E.g. for carbon-content of milk that measure may be 0.20 € per kg CO_2 per liter milk meaning that increasing the carbon footprint of one liter milk by 1 kg impacts the demand for milk like a price increase by 0.20 € per liter. These relations represent marginal willingness-to-pay, also known as part-worths or part-worth utilities, of the attributes. For the multinomial probit these values are calculated at the sample mean while they are constant in the MXL.

3. Results

Descriptive Statistics

275 questionnaires represent our data base while 309 questionnaires had been handed out to consumers forming a convenience sample. The lower part of table 3 gives an overview about the participants in the experiment. Half of them are woman, on average two and a half persons live in a household only 0.4 of which are children younger than 15 years. The average age of the respondents is 41, while the age distribution is skewed to the right both indicating that – for Germany – young respondents are overrepresented in the sample. Income is measured in income classes starting with less than 500 € per month and increasing in steps of 500 € up to 2499 € per month. The two highest classes are 2500 € to 3999 € and 4000 € and more per month. This scale was a compromise with the supermarket's executive officer who did not want us "to annoy my customers with detailed questions on their income". For the regressions income per head is calculated as the ratio of the income variable relative to the number of

household members (= household size). On average, households had been in the fourth income class between 2000 € and 2499 € per month. Taking into account the income ranges of the two highest income classes the average household was well above 2500 € per month indicating that 'rich' households are over-represented here. This is not a surprise since the supermarket where consumers had been asked for the survey is not a discount store. Control variables on education finish the respondents' characteristics.

Each consumer had been confronted with six choice sets for milk and apple juice, respectively. 1636 milk choices were analyzed while 1626 choices were suitable for the apple juice regressions. The milk and juice choice sets in the questionnaires differ only in their carbon footprint and price levels (see table 2). Thus, the locality of the supply chain and the number of organic products are virtually equal for both products with 265 kilometers for the supply chain and 64% organic alternatives. On average the carbon footprint for the milk alternatives was 0.99 kg CO_2 per liter and the price was 0.59 € per liter milk. The average carbon footprint for juice amounted to 0.2 kg CO_2 per liter and the juice price to 0.79 € per liter.

Table 3. Summary statistics of attribute levels and respondents

		MILK		**APPLE JUICE**	
variable		mean	standard deviation	mean	standard deviation
carbon footprint	kg CO_2 per liter	0.99	0.81	0.20	0.16
price	€/liter	0.59	0.16	0.79	0.33
local supply chain	km	265.72	179.2	265.39	179.40
organic production	yes = 1	0.64		0.65	

		respondents' characteristics	
		mean	standard deviation
household income	seven income classes	4.32	1.87
household size	number	2.48	1.24
age	years	41.36	18.50
sex	female = 1	0.50	
school education	four levels of education	2.67	1.08
job education	none = 0, non-academic = 1, academic = 2	0.47	0.78
children	number	0.36	0.78

Estimation results

We focus on the influence of the attribute levels – price, carbon footprint, organic production, local supply chain, and brand – on the respondents' choices. Then marginal willingness-to-pay values for the attributes are calculated. The impact of personal characteristics will be discussed in short at the end of the results section.

We estimated rich models including all variables from the descriptive statistics table 3 for milk and apple juice. We estimated both multinomial probit regressions and mixed logit regressions. In a second step, the number of right hand side variables is reduced based on likelihood ratio LR tests to get sparse regressions. We start with the milk. A Hausman test rejected the IIA assumption on the 1% level. The rich specifications resulted in a log likelihood (LL) value for the MXL of -1260.5 and the simulated log likelihood in the MNP was -1454.0. Table 4 displays the estimates for the attributes from the sparse specifications. The LL values are close to the respective values of the rich specifications indicating that the sparse specifications are reasonable.[1] The direction of the attributes' influence is as one might expect. The higher the carbon footprint and the higher the price the lower is the probability that this milk alternative is chosen. In contrast, the more local the supply chain is organized the higher is the probability to choose this milk. Organic milk production on the farm results also in a higher choice probability for milk. The negative sign for both labels indicates that they are less attractive than the third offered label *Bärenmarke* – a national premium label for milk which is the reference for the two labels in these specifications.

[1] The LR test results are available from the authors.

Table 4. Estimation results for milk attributes (sparse specifications, 1636 choice sets)

MILK sparse specifications	**mixed logit (MXL)**			**multinomial probit (MNP)**		
log likelihood (LL)	-1263.2			-1458.4 (simulated LL)		
attributes	coefficient	standard error	Prob >|z|	coefficient	standard error	Prob >|z|
carbon footprint	-1.13	0.11	0.000	-0.39	0.04	0.000
Price	-6.31	0.62	0.000	-2.38	0.22	0.000
local supply chain	0.00547	0.00052	0.000	0.00204	0.00019	0.000
organic production	1.16	0.15	0.000	0.48	0.07	0.000
supermarket's label	-1.52	0.57	0.007	-0.39	0.06	0.000
regional label	-1.47	0.60	0.015	-0.41	0.06	0.000

Table 5. Part-worth utilities for milk attributes (sparse specifications)

MILK sparse specifications		part-worth utility	
attributes	unit of part-worth utility	**mixed logit**	**multinomial probit**
carbon footprint	€ per kg CO_2	0.18	0.16
local supply chain	€ per 100 km	- 0.09	- 0.09
organic production	€ if organic	- 0.18	- 0.20
supermarket's label	€ if supermarket's label	0.24	0.16
regional label	€ if regional label	0.23	0.17

Table 5 displays the part-worth utilities – or marginal willingness-to-pay – for the milk attributes. They represent the (negative) marginal utility of a one unit change in the attribute expressed in monetary terms. E.g. the 0.18 in the first row mean that an increase of one kilogram CO_2 emissions per liter milk is equivalent to a price increase of 0.18 € per liter. 'Equivalent' here means that the impact on the choice probability is equal. The differences between the part-worth utilities from both estimations are rather small indicating that the results are stable between both estimation procedures. The results for the organic production attribute as well as for the two labels can be compared to real-world price premiums for organic milk and a premium label for milk. An organic price premium of around 0.20 € per liter seems to be reasonable for the average respondent. In German supermarkets the actual price premium for organic milk is higher in general, but the market share is much below 50% indicating that the average consumer is not willing to buy organic milk for the high real-world price premium. The part-worth utilities for the two labels indicate that switching from the premium label to one of the alternative labels is equivalent to a price increase (for the premium milk) of 0.16 € to 0.24 € per liter. This price premium for premium milk is realistic for Germany.

The part-worth utility of the milk's carbon footprint amounts to 0.18 € and 0.16 € per kilogram CO_2 per liter milk in the mixed logit and the multinomial probit, respectively. Consequently, one kilogram more carbon footprint per liter milk has - *ceteris paribus* – the same impact on the average consumer's choice like a price increase by 0.18 and 0.16 € per liter milk. This value indicates some demand potential for carbon-reduced or carbon-neutral milk. Depending on the milk's carbon footprint a price premium for carbon-neutral milk of around 0.20 € per liter can be estimated.

For the apple juice regressions 1626 choice sets were used. A Hausman test rejected the assumption of IIA on the 0.1% level. The rich specification for the MXL amounted to an LL value of -1272.9 while the simulated LL for the MNP model is -1458.4. Again, some variables can be restricted to zero. The LL values of the spares specifications do not differ significantly from the rich specifications' values as can be seen from table 6.[2] In general, the regression results for apple juice in table 6 are in line with the milk estimates. The higher the carbon footprint and the higher the price the lower is the probability that this juice alternative is chosen. In contrast, the more local the supply chain is organized and if apple production is organic then the probability of choosing this juice alternative increases. The influence of the different labels is not significant in the MXL model while the MNP model indicates that the premium label *hohes C* increases the choice probability only compared to the retailer's label. The regional apple juice *Becker's Bester* increases the choice probability compared to what we expected to be the premium label *hohes C*.

The differences between the part-worth utilities from both estimations in table 7 are again small indicating that the results are stable between both estimation procedures. Exceptions are the labels. An organic price premium of around 0.30 € per liter juice seems to be reasonable for Germany. The same arguments as for the organic milk apply. The part-worth utility for the juice's carbon footprint amounts to 0.81 € and 0.90 € per kilogram CO_2 per liter juice in the mixed logit and the multinomial probit, respectively. Consequently, a carbon-neutral apple juice is expected to allow for a price premium of 0.32 € and 0.36 € per liter compared to an apple juice with 0.4 kg carbon footprint. This value indicates some demand potential for carbon-reduced or carbon-neutral apple juice.

[2] The LR test results are available from the authors.

Table 6. Estimation results for apple juice attributes (sparse specifications, 1626 choice sets)

APPLE JUICE sparse specifications	**mixed logit (MXL)**			**multinomial probit (MNP)**		
log likelihood (LL)	-1284.8			-1466.7 (simulated LL)		
attributes	coefficient	standard error	Prob >|z|	coefficient	standard error	Prob >|z|
carbon footprint	-3.17	0.40	0.000	-1.21	0.17	0.000
price	-3.90	0.33	0.000	-1.34	0.11	0.000
local supply chain	-0.0048	0.0005	0.000	-0.0019	0.0002	0.000
organic production	-1.27	0.15	0.000	-0.45	0.06	0.000
supermarket's label	-0.43	0.31	0.168	-0.12	0.05	0.018
regional label	-0.04	0.36	0.916	0.09	0.05	0.046

Table 7. Part-worth utilities for apple juice attributes (sparse specifications)

APPLE JUICE sparse specifications		Part-worth utility	
attributes	unit of part-worth utility	**mixed logit**	**multinomial probit**
carbon footprint	€ per kg CO_2	0.81	0.90
local supply chain	€ per 100 km	0.12	0.14
organic production	€ if organic	0.33	0.34
supermarket's label	€ if supermarket's label	0.11 §	0.09
regional label	€ if regional label	0.01 §	-0.07

§ = not significant

Finally we turn to the impact of personal characteristics on choosing among the different labels. The sparse specification for apple juice revealed that in the MNP model all respondent characteristics can be restricted to zero. In the MXL for apple juice the household income cannot be restricted to zero in addition to all attributes. But the income is only jointly significant with the label dummies. For milk both models MXL and MNP reveal that the choice probability for the retailer's label and for the regional label decrease with household income. This is reasonable as we expect a higher preference or stronger habit to choose the premium label for 'richer' households. This is in line with the negative impact of the household size on these two choice probabilities in the MXL model. In the MNP model the relationship between income and household size on the choice probability of the two milk labels is more complicated. The interpretation is left for further research since the income variable should be specified more sophisticated for in-depth analysis of the income's impact due to the different class ranges for the income variable, e.g. dummies for the highest two income classes may be useful.

4. Discussion and Conclusions

The part-worth utilities reveal substantial price premiums for both carbon-neutral milk and carbon-neutral apple juice. Offsetting 1.4 kg CO_2 per liter milk and 0.4 kg CO_2 per liter apple juice is equivalent to a price premium of more than 0.20 € per liter milk and more than 0.30 € per liter apple juice. Since carbon credits only cost less than 5 € per ton CO_2 in Europe (eex, December 2013)[3] or 0.005 € per kg there seems to be some profit potential for milk and apple juice suppliers.

However, the external validity of all stated preference methods is – in general – limited. On one hand, respondents tend to socially desirable choices. Consequently, in our analysis the willingness-to-pay for carbon-neutral milk and juice is probably overestimated. In particular, the estimate for the local production seems quite high. On the other hand, among the stated preference methods Discrete Choice Experiments have a high external validity. However, carbon-neutral milk and juice are not yet commonly available in German supermarkets. Thus, there is no alternative to stated preference methods. Another problem is that our convenience sample of respondents is not representative. One should not transfer our estimates to consumer groups which tend to buy their food at discount food stores. So, our estimates are a first step for producers and retailers which should be complemented by more market research such as experimental launching of these products in selected supermarkets.

Another problem for market launch of carbon-neutral products is credibility since carbon-neutral goods are (partially) credence goods. Do consumers trust in labeling a product to be carbon-neutral? Here governments can probably help with labeling or at least with setting the rules for labeling and monitoring the labeling organizations. The experience from organic products is probably helpful here.

This paper showed that one can expect demand for carbon-neutral milk and apple juice in Germany. Consumers seem to be willing to pay a price premium which probably covers extra costs for these new food products, including costs for carbon credits to offset the production-related carbon footprint of the two beverages. Consequently, these new products offer a way to internalize some of the climate-related external costs by producing and consuming milk and apple juice. Although this is not a first-best policy

[3] Due to the European economic recession, today's carbon credit prices in the EU are relatively low, e.g. two years ago the price was around 10 €/t (eex, November 2013). But today's prices can be expected to increase since the EU aims at reducing the number of credits between 2013 to 2015.

to fight the climate impact of food this voluntary approach has one big advantage: poor costumers need not to pay more for their food. In contrast to greenhouse gas emission taxes or carbon credits this measure does neither impact the poor nor the hungry.

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