Does the carbon footprint enhance the sustainability food production and transportation service system? Real buying experiment in Japan

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Abstract. To examine whether the carbon footprint induce the sustainability local food production and service system, this study investigate the relationship between consumers' environmental consciousness and willingness to pay for carbon dioxide emissions on food products by using a choice experiment under the real buying experiment. The results show that consumers with higher environmental consciousness value the higher WTP for the reduction of carbon dioxides.

Keywords: Carbon footprint, Local food system, Transportation, Choice experiment, Experimental economics

1 Introduction

A carbon footprint aims to indicate and visualize the amounts of carbon dioxide (CO_2) emissions caused in the process from production to disposal as the life cycle of the food products in order to motivate consumers and producers to buy and produce the food with lower emissions, respectively.

Onozuka and McFadden (2011) show that increasing the CO_2 emissions induces the negative WTP for the food consumption but local labels mitigate that negative impact [1]. Thus, consumers have a preference for the local foods. This is the biggest difference in the carbon footprint between food products and non-food products such as electric products and other daily commodities. The local food system, that is, local productions for local consumptions, maintains the food as more fresh and the taste as better, which attracts consumers more to the local foods than to the foods produced in the far distance. Growing the local food system induces a few energy spending for the transportation and larger consumptions with reducing the waste of disposals, which more advances to mitigating the CO_2 emissions and enhances the sustainable food

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system. In this meaning, carbon footprints will become important role to disseminate the local food production and service systems to attain the sustainability food system.

There is, however, still open question whether the consumers want to reduce CO_2 emissions caused from the transportation and local food system is proceeding. To examine this question, a simply hypothesis is tested in this study. It is that consumers with higher environmental consciousness exhibit the higher willingness to pay for the reduction of CO_2. To examine this hypothesis, there are the three steps in this study as follows.

First, the selected consumers' ecological purchase behaviors scale originally developed by Roberts (1996) is used to evaluate environmental consciousness for consumers [2].

Second, the choice experiment is used to estimate the value of the carbon dioxide emissions. The choice experiment consists of three alternative oranges including two attributions; price and amounts of CO_2 emissions. The choice experiment approach used in this study is a type of stated preference method [3] useful for effectively overcoming certain biases (e.g., strategic bias, compliance bias, and warm glow bias).

Following Experimental Economics method, the choice experiment condition is real buying experiment. In this experiment, respondents are given real money and buy one of three oranges in 12 times to take them home.

The seminal experimental study of generally called eco-labels is Cason and Gangadharan (2002), which find the eco-labels clear the market adverse selection caused from the information asymmetric between consumers and producers [4]. In the food markets, for example, experimental studies include fair trade [5, 6] , organic labels [7], genetically modified label [8-11]

The remaining paper is organized as follows. Section 2 explains the survey and experimental design and procedures. Section 3 describes the empirical model structure. Section 4 analyzes the results, and Section 5 summarizes the conclusions and discussions.

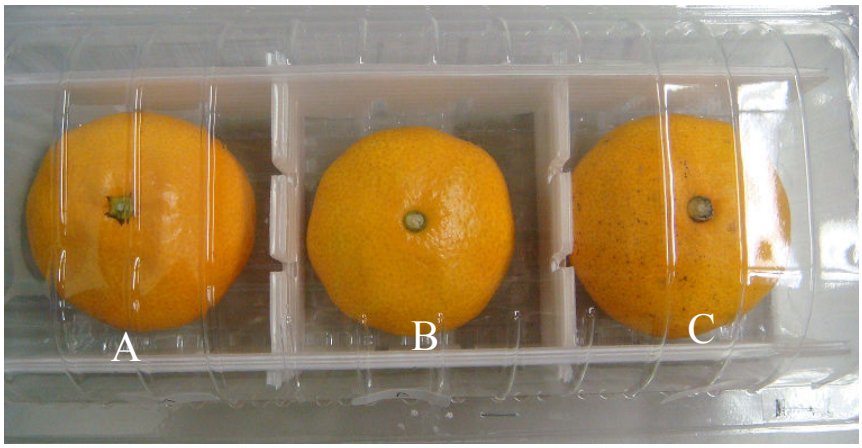
2 Experimental design and procedure

The experimental design and procedures replicate the previous study of Aoki et al. (2010), who find the hypothetical bias for the consumers' reactions of information of sodium nitrite on the ham [12].

Figure 1 shows the example of designated choice sets and the alternatives are three types of oranges A, B, and C.[1] The type of oranges is called Satsuma mandarin oranges (Citrus unshiu Marc.),which is the representative domestic fruit in Japan.[2] Each alternative constitutes two types of attributions; the price and the amounts of CO_2 emissions. The levels of the price attribute have three values: 25, 35, and 45 JPY

[1] Following Aoki et al. (2010), "no-purchase" alternative is not added in the choice experiment

[2] Each orange was approximately 7 cm in diameter and its weight was approximately 100g. Its color was orange with a bluish tinge. The sugar content in them was approximately 9 to 11 brix.



	Orange A	Orange B	Orange C
Price	35	25	45
Carbon dioxide emissions	30	20	40
I would choose…	□	□	□
The most important reason affecting my choice	□Price □Carbon dioxide emissions □Appearance □Others [A reason:]		

Fig. 1. An example of choice sets and oranges

per one unit of orange. These levels are based on the prices of oranges in the three largest supermarkets around Osaka University.

The amounts of the CO_2 attribute also have three values; 20g, 30g, and 40g per one unit of orange, which are calculated the four stages of their life cycle: production, fruit sorting and box packing, transportation, and packaging.[3] To cope with a rule for the prohibition of deception in Experimental Economics, three different places producing oranges are actually selected to make the difference of CO_2. Since the carbon footprint is to be prepared in Japan, the CO_2 emissions are first calculated on the life cycle assessment (LCA) to select those places. Then, the oranges are selected three famous places; Kumamoto, Ehime and Wakayama. The experiment is conducted in Osaka prefecture that is the most far from Kumamoto (about 800km), second from Ehime (about 380km) and third from Wakayama (about 100km). Thus, the transportation causes the main difference of CO_2 emissions in this study. The total CO_2 emissions are calculated as 34g, 32g, 23g in Kumamoto, Ehime and Wakayama, respectively. Based on these three values, the three values are employed as 20g, 30g, and 40g. Respondents, however, does not receive the places nor the CO_2 emitted in each process to make respondents focus on only price and the total amounts of CO_2 emissions in the food products.

[3] The levels of CO_2 emissions of oranges during their sale in supermarkets and stores are not added because a number of other goods are present there.

A full factorial design with three levels of prices and three amounts of CO_2 emissions constructed 729 alternative management combinations. Since it constitutes an unreasonably large design in practice, a D-optimal fractional factorial design with 24 alternatives is developed and separated into two blocks of 12 choice sets by using Design Expert (version 7). Therefore, each respondent choose one of three oranges and this repeats 12 rounds. The respondents received 120 JPY as endowment in order to purchase one unit of orange and a plastic package contained three types of oranges. The package was clear to see inside but sealed to keep respondents' hands off. They selected one of the oranges they wanted to buy. The price of the oranges they selected is deducted from the endowments and the total remaining money is paid as their earnings at the end of the experiment.

After twelve choice sets completed, respondents answer the survey questions about environmental consciousness (EC) scale, which is consisted of 10 questions used in Johnston et al. (2001) [13]. These are parts of the consumers' ecological purchase behaviors scale developed by Roberts (1996), which is consisted of 30 items measuring socially responsible consumer behavior using two dimensions; societal and ecological concerns. The question is asking respondents to rate the veracity of various statements with respect to their purchase behavior and its connection to environmental product attributes. It is five-point Likert type scale which denotes 1 as "never agree" to 5 as "always agree."

3 Model Structure

The study is used a random parameter logit (RPL) model [14, 15] based on the random utility theory which is central to the concept of choice modeling. The basic assumption underlying the random utility approach to choice modeling is that decision makers are utility maximizers, which implies that given a set of alternatives, decision makers select the alternative that maximizes their utility. The utility of an alternative for an individual (U) cannot be observed; however, it may be assumed to consist of a deterministic (observable) component (V) and a random error (unobservable) component (ε). Formally, an individual q's utility of alternative i in each of t choice set can be expressed as $U_{iqt} = V_{iqt} + \varepsilon_{iqt} = \beta'_q X_{iqt} + \varepsilon_{iqt}$. The density of β'_q is denoted as $f(\beta|\theta)$, where θ is a vector of the true parameters of the taste distribution. X_{iqt} denotes the explanatory variables of V_{iqt} for alternative i, individual q and choice set t. The random error component ε_{iqt} is assumed to follow a type I extreme value (EV1) distribution and to be independently and identically distributed (IID). The conditional probability of alternative i for individual q in choice set t is expressed as follows:

$$P_{iqt}\left(\beta'_q\right) = \frac{exp\,(\beta'_q X_{iqt})}{\sum_{j=1}^{J} exp\,(\beta'_q X_{jqt})} \quad , \tag{1}$$

The probability of the observed sequence of choices conditional on knowing β'_q is expressed as follows:

$$S_q\left(\beta'_q\right) = \prod_{t=1}^{T} P_{qi(q,t)t}\left(\beta'_q\right), \quad (2)$$

where $i(q,t)$ represents the alternative selected by individual q on choice set t. The unconditional probability of the observed sequence of choices for individual q is the integral of the conditional probability over all possible variables of β'' and can be expressed as follows:

$$P_q(\theta) = \int S_q(\beta) f(\beta|\theta) d\beta. \quad (3)$$

In most applications, the density $f(\beta|\theta)$ is specified to be normal or lognormal: $\beta \sim N(b,W)$ or $\ln\beta \sim N(b,W)$, where the mean, b, and covariance, W, are estimated. In this study, we use a normal density.

Based on the above discussion, the main effect in Model 1 and the main effect with interaction in Model 2 are estimated using RPL model with the inclusion of socioeconomic characteristics. Therefore, the two indirect utility functions are as follows:

Model 1: $V_{iq} = \beta_1 Price_i + \beta_2 CO2_i,$

Model 2: $V_{iq} = \beta_1 Price_i + \beta_2 CO2_i + \sum_{k=1}^{K} \delta_k CO2_i \times Socio_{kq}.$

where $Price_i$ is the price of orange i, $CO2_i$ is the CO_2 emission from orange i, and $CO2_i \times Socio_{kq}$ is the interaction term of the CO_2 emission from orange i with a dummy variable indicating socioeconomic characteristics k of individual q, including the EC scale. β_1, β_2, and δ_k are parameters that need to be estimated.

4 Results

The laboratory experiment was conducted at the Osaka University with 104 respondents (63 non-students and 41 students) during November at the beginning of the season of the orange. No one participated in more than one session. Each session lasted for approximately 60 minutes. The average earnings in experiment was 1,407 JPY.

Table 2 summarizes the result estimated from LIMDEP 9.0 and NLOGIT 4.0. In the RPL model, a simulated maximum likelihood estimator is used in order to estimate the models by employing Halton draws with 500 replications [16, 17].

First result is the main effect of Price and CO_2. The variable Price is the fix parameter in the model because a price coefficient is known to be negative for every consumer. However, since the variable CO_2 is not known, it is assumed as a random parameter and specified to be normally distributed [14, 16]. The estimates of the two variables, Price and CO_2, indicate significantly negative signs at 1% levels. These results imply that all the respondents prefer to purchase oranges whose price is cheaper and CO_2 is lower. The marginal WTP for the reduction of 1g of CO_2 emission per an orange is 0.57.

Next result is the main effect with the interactions of CO_2. Here there is the main

Table 1. The random parameter logit regression results

Variable	Main effect	Main effect with interactions
Price	-0.12*** (0.01)	-0.12*** (0.01)
CO_2	-0.07*** (0.01)	-0.04* (0.02)
CO_2: Standard deviation	0.08*** (0.02)	0.07*** (0.02)
CO_2: Marginal WTP (mean)	0.57	0.33
[95% confidential bounds]	[0.55;0.58]	[0.32;0.34]
CO_2*High EC		-0.05*** (0.01)
CO_2*Female		-0.04** (0.02)
CO_2*Over 30		0.02 (0.02)
CO_2*High Income		-0.01 (0.01)
CO_2*University		0.02 (0.02)
Log likelihood	-1107.62	-1093.73
McFadden's R^2	0.19	0.20
Observations	1248	1248

Notes: Standard errors are in parentheses. ***, **, and * denote that the parameters are different from zero at the 1%, 5%, 10% significance levels, respectively.

Table 2. The dummy variables

Variables	Definition	Average
High EC	1: more than the median (30); 0: otherwise.	0.49 (0.50)
Female	1: female; 0: male	0.65 (0.48)
Over 30	1: more than 30 years old; 0: otherwise.	0.58 (0.49)
High Income	1: more than the median; 0: otherwise.	0.49 (0.50)
University	1: graduation university; 0: otherwise	0.86 (0.35)

Notes: Standard errors are in parentheses. Median of high income is 5,500,000 JPY.

hypothesis such that consumers with higher EC scales exhibit higher WTP for reduction of CO_2. The estimation model is added the five interaction variables to the two variables Price and CO_2; *High EC*, *Female*, *Over 30*, *High Income*, and *University*. These variables are summarized in Table 2. Since spearman correlation rank-tests show significantly positive correlations at the 1% level in any combinations of EC, EK, and EB, EC is used as a representative variable for the evaluation of consumers' environmental consciousness.

The results are as follows. Consumers have significantly negative coefficients for the increasing CO_2. The consumers with higher environmental consciousness exhibit higher WTP for reduction of CO_2 than those with lower environmental consciousness, which supports the main hypothesis. The result implies that the carbon footprint mitigate the emissions caused from the long distance transportation and enhance the local food production and service systems.

5 Conclusions and discussions

This study investigates the relationship between consumers' environmental consciousness and their valuations for the carbon footprint on daily food products by using the choice method in the real buying experiment. The results support the main hypothesis such that consumers with higher environmental consciousness have a higher WTP for the reduction of CO_2 in the experiment.

The oranges used in this study have the almost same production procedures so that their CO_2 emissions are not so far. The largest difference in the CO_2 emissions caused from the transportation because of the difference from the transportation distances. Although this study does not inform the breakdown of CO_2, the result implies that consumers prefer for foods produced in the near areas because of reducing emissions from the transportation.

In this study, the difference of the distance in the production area causes the difference in the carbon dioxide emissions. The result implies that the carbon footprint has a power to enhance the local food productions for the local consumptions and reduce the emissions caused from the long distance transportation.

Since this study investigates the value of reduction for the CO_2 emissions on foods in the real buying experiment, a question is created as future works. That question is whether the value in the hypothetical condition is more than that in the experiment, which is a hypothetical bias. A choice experiment has a hypothetical bias risk. Harrison and Rutström (2008) surveyed 35 studies and found hypothetical bias in all but 3 cases, which implies that researchers rarely find a situation without hypothetical bias [18]. In the food market, Lusk and Schroeder (2004) found it for beef ribeye steak [19], and Chang et al. (2009), for ground beef and wheat flour [20]. Most recently, Aoki et al. (2010) found it in sodium nitrite information on hams. Hypothetical bias causes policy makers to suspect the credibility of policy evaluation data.

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