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Consumer perceptions of climate change and willingness to pay for mandatory implementation of low carbon labels: the case of South Korea

RESEARCH ARTICLE

Hyeyoung Kim[a], Lisa A. House[b], and Tae-Kyun Kim[Ⓘc]

[a]Assistant Research Scientist and [b]Professor, Food and Resource Economics Department, University of Florida, P.O. Box 110240, Gainesville, FL 32611, USA

[c]Professor, Department of Agricultural Economics, Kyungpook National University, 80 Daehakro, Bukgu, Daegu 41566, Republic of Korea

Abstract

The purpose of this study is to examine consumer values for mandatory carbon labels incorporating South Korean consumers' perceptions about climate change using conjoint analysis. In a face-to-face consumer survey, we asked about individuals' perceptions of the impact of climate change on their personal lives to measure its effect on consumer preference for carbon labels. The results of ordered logit and conditional logit regressions showed that a significant preference for mandatory carbon labels reflected Koreans' level of concern about climate change. As an increasing number of consumers feel the impact of climate change, the gap of willingness to pay between voluntary and mandatory low carbon labels is significant. Also, consumer perception of the impact of climate change on their personal lives was significantly influenced by the area in which the respondents' lived.

Keywords: carbon labeling, climate change, mandatory labels, awareness, WTP
JEL code: D12, P36, Q54

Ⓘ Corresponding author: tkkim@knu.ac.kr

1. Introduction

Climate change due to high levels of greenhouse gas (GHG) emissions in the atmosphere has become an important issue in the world. Global warming threatens to raise sea levels, exterminate species, and threaten food security (Cox *et al.,* 2000; Vitousek, 1994). In response, more than 160 international parties adopted the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 as the global legal policy framework and agreed to the Kyoto Protocol in 1997 as realistic rules for implementation. More recently, the Intergovernmental Panel on Climate Change (IPCC) pointed out human activities as one of the main causes for global GHG emissions, especially industrial activities (IPCC *et al.,* 2007). In response to this, countries, retail chains, and non-government organizations in the world have established carbon labels to inform consumers of the environmental impact of the products they consume.

The main role of product labels is to turn 'credence' attributes into 'search' attributes. This new information may influence consumers when they make product decisions if consumers perceive the information as important. For example, nutritional labels represent the nutrient content of food and can influence consumers' food purchases because of their perception of the health of the product based on the label information (Chang and Nayga, 2011; Kim *et al.,* 2012; Teisl and Levy, 1997). Consumers who purchase products with carbon labels may obtain utility in terms of both public satisfaction through participating in the reduction of carbon emissions and reduction of global warming, as well as private satisfaction through consuming clean air in their daily lives (Cohen and Vandenbergh, 2012; Michaud *et al.,* 2013). In some cases, low carbon products such as cars and appliances may directly increase the private utility of consumers by reducing their spending on gas or electricity.

Carbon labels are voluntarily adopted in most countries. Gadema and Oglethorpe (2011) pointed out the limited effect of voluntary systems on the reduction of carbon emission. Although producers or retailers may be interested in the label, this will likely only occur if the label directly or indirectly relates to increasing profit. For example, Tesco, a retailer in the U.K. reported that they would stop presenting carbon labels because of the cost of maintaining the labels (Quinn, 2012). In South Korea, 13.6% of companies indicated that they had a program to reduce carbon emission or had a plan to do it (Ministry of Environment, 2007, 2008). However, most companies develop the program not to provide environmental information of the product to consumers but to meet the standards of importing countries for exporting their products to the counties.

Because of growing interest in this issue, many researchers have attempted to understand consumer perception of carbon labeling and attitudes about climate change (Kemp *et al.,* 2010; Kim, 2011; Upham *et al.,* 2011). However, the studies have neglected to develop a linkage between consumers' perceptions about climate change and consumer value for the carbon labels. In addition, few studies have measured the value of mandatory carbon labels, although previous studies established a consensus that voluntary carbon labels were not very effective at reducing GHG emission (Cohen and Vandenbergh, 2012; Gadema and Oglethorpe, 2011). Note that mandatory labels require companies to produce products with reduced carbon emissions by law. Therefore, this study aims to further the literature regarding Korean consumers, as well as by investigating the difference in consumer values between mandatory and voluntary labels by incorporating individual perceptions about the impact of climate change on their personal lives.

In this study, a choice experiment (CE) analysis was used to estimate the value of carbon labels depending on levels (measured and low carbon labels) and types of implementation (voluntary and mandatory). We expected consumer preference for carbon labels to vary based on their individual attitudes toward climate change. The impact of climate change on individuals' lives was measured to predict the effect of individuals' attitudes toward climate change on preference. Consumers who strongly perceive the impact of climate change may be willing to pay extra to purchase products with low carbon labels and may prefer mandatory carbon labels.

We selected fresh apples to derive policy implications of availability of low carbon production in agricultural products. We selected this product because apples are one of top three fresh fruits consumed in South Korea and they can be purchased year round. Even though the Ministry of Environment, who is administrating the carbon labeling, stated that basic agricultural products (in their original form or having undergone only primary processing) are not targeted for carbon labeling, the Ministry of Agricultural, Food and Rural Affairs have conducted several pilot projects for basic agricultural products to test implementation of low carbon labels since 2012. The following sections will present an overview of carbon labels, examine the measured values of carbon labels according to previous studies, and present the research method, findings, and conclusions of this study.

2. Overview of carbon labels

Global carbon labels

Introducing carbon labeling has symbolic meaning in developing world economies which implies that international leaders seek not only quantitative growth but qualitative growth of the world economy by considering global environment change. Unlike Eco Labels, which provide qualitative emission information of products, most carbon labels are designed to show quantitative emissions of carbon or GHG equivalent while a product is grown, manufactured, transported, used, and disposed. Despite controversial problems related to interpretation of the numerical values on carbon labels (Upham *et al.,* 2011), carbon emissions play a role in informing consumers of the environmental implications of their economic activities. Selected carbon labels are shown in Table 1.

The first carbon labeling in the world was the Carbon Footprint label created by the Carbon Trust in the UK in 2006. The Carbon Trust offered two types of Carbon Footprint labels, Reducing CO_2 Label and CO_2 Measured Label. The Reducing CO_2 Label certified that companies committed to reduce the level of CO_2 emissions resulting from the production and distribution of the products. The Carbon Trust required re-certification of the Reducing CO_2 Label every two years. To recertify, companies must prove that they have reduced the amount of CO_2 emissions. The CO_2 Measured Label only indicates that the footprint of the products is accurately measured. Both certifications must meet the requirements in the PAS 2050 and/or the WBCSD-WRI GHG Protocol Product Standard.

Supermarket channels in European countries created carbon labels to inform consumers of the environmental impact of the products in response to global trends. Carbon labels may also promote a positive image of the supermarket by showing their desire to take care of the environment. In France, Casino initiated a carbon labeling program called Indice Carbone in 2011 which provided quantitative CO_2 emissions, recycling

Table 1. Selected carbon labels by country.

	Carbon labels by country				
	Reducing CO_2 Label	**Indice Carbone**	**Climatop**	**Certified Carbon*Free*™**	**CFP mark**
Country	UK	France	Swiss	USA	Japan
Label	CARBON TRUST REDUCING CO2	INDICE CARBONE 55g de CO_2 voir au dos	approved CO_2 by climatop	CERTIFIED Carbonfree Carbonfund.org	123g CO_2
Web source	carbontrust.com	produits-casino.fr	climatop.ch	carbonfund.org	cfp-japan.jp

information and additional information about the environmental impact of use and disposal of products. In Switzerland, Migros introduced a carbon label called Climatop comparing carbon emissions to that of similar items. Products displaying Climatop indicate that the product's emissions are 20% lower those of its counterparts within the same product category.

In the USA, Carbonfund.org, a nonprofit provider of climate solutions, created a label called Certified Carbon*Free* in 2007. Products obtain the Carbon*Free* label when they meet the standards of PAS 2050:2008, ISO Standard 14044:2006 or WBCSD-WRI Greenhouse Gas Protocol for corporate GHG reporting. Also, products are qualified for the Carbon*Free* product certification program as long as the products have received the Carbon Trust and the Carbon Pollution Reduction Scheme developed by the Australian Government. Aside from Carbon*Free*, the Energy Star label provides energy efficiency information for appliances. Murray and Mills (2011) estimated that Energy Star appliances are associated with carbon emission reductions of about 1.1 million metric tons per year.

In Japan, the Japan Environmental Management Association for Industry (JEMAI) started new carbon footprint of products (CFP) programs based on ISO 14067 in 2012. The main features of CFP programs are CFP-product category rule certification, CFP verification, and verification of Emission Factors conducted by third party experts.

Carbon labels in South Korea

South Korea's GHG emissions accounted for 1.3% of the world total in 2005. However, South Korea's emissions increased 71.6% on a per capita basis over the period of 1990 to 2005 which is far outstripping the OECD average of 2.1% (OECD, 2010). In 2008, the president proclaimed 'low carbon/green growth' as the vision to guide Korea's development during the next 50 years, and in 2009, South Korea voluntarily set a goal of cutting its GHG emissions by 30% relative to a 'business as usual' baseline by 2020 (OECD, 2010). In line with the national strategy for Green Growth, the government has encouraged firms to develop green technologies and is also aware of the importance of consumer participation. As such, South Korea introduced a carbon labeling system for daily household supplies and home appliances in February 2009 in order to reduce GHG emissions by leading consumers to low carbon products and by encouraging companies to develop new technology which can reduce emission levels. Under the administration of the Ministry of Environment, the Korea Environmental Industry and Technology Institute (KEITI) issues two different levels of carbon labeling: carbon emission certification (CEC) (Figure 1A) and low carbon product certification (LCPC) (Figure 1B). The original labels are translated to English in Figure 1. Similar to the CO_2 Measured Label of the Carbon Trust, the CEC is issued if products are officially examined for emission levels and meet standard GHG emission levels. The LCPC is issued for a product which already obtained the CEC if the company successfully develops techniques to reduce a certain amount of GHG emissions to produce that product. The LCPC is similar to the Reducing CO_2 Label of the Carbon Trust. Currently, 371 products obtained LCPC out of 1,640 total certified products (Korea Environmental Industry and

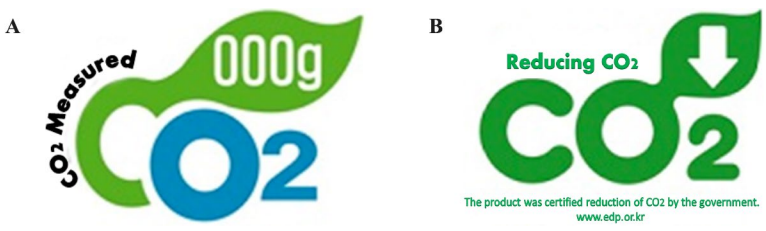

Figure 1. Translated carbon labels in South Korea. (A) carbon emission certification; (B) low-carbon product certification (adapted from Korea Environmental Industry and Technology Institute: http://tinyurl.com/zd8pubz).

Technology Institute: www.edp.or.kr). This indicates that companies are less likely to invest in developing new technology to reduce GHG emissions.

3. Measuring values of carbon labels

CEs have widely been used to measure consumer willingness to pay (WTP) for attributes of products. In particular, CEs have been used to examine values of different types of labels such as nutritional labels, health labels, ingredient labels, GMO labels, country of origin labels and food mileage labels. Although Lusk and Schroeder (2004) pointed out the hypothetical bias in CEs, CEs are relatively cost effective and enable large coverage compared to experimental auctions, which may reduce hypothetical bias. Also, Lusk and Schroeder did not find a statistical difference of marginal WTPs between CEs and experimental auctions. Studies based on consumer surveys have showed that consumers positively valued low carbon emissions and had higher WTP for low carbon products than high carbon products. Many studies have focused on measuring WTP for non-agricultural products such as green power (Borchers *et al.,* 2007; Clark *et al.,* 2003), appliances (Sammer and Wüstenhagen, 2010) and automobiles (Hidrue *et al.,* 2011), while several studies have examined the value of low carbon emission agricultural products.

Michaud *et al.* (2013) examined WTP for roses to determine consumer values of carbon labels for non-food agricultural products. They conducted a discrete CE with real purchases of roses associated with an eco-label and a carbon footprint label in France. The results of the mixed logit model indicated that consumers significantly valued environmental attributes and the value of a low-carbon footprint was considerably greater than eco-labels (low fertilizer). The premium for roses with a low-carbon footprint was approximately 2.4 times larger than eco-labeled roses.

Aoki and Akai (2013) and Loureiro *et al.* (2002) used food products to compare WTP for environment friendly foods. Aoki and Akai performed a real CE to compare consumer WTP for the reduction of CO_2 emissions for Satsuma mandarin oranges based on consumer attitudes toward the environment in Japan. They used three environmental factors: environmental consciousness (EC), environmental knowledge (EK) and environmental behavior (EB) in daily life. Consumers were categorized into two groups with high and low attitudes of EC, EK and EB. The results of the random parameter logit model indicated that only environmental consciousness led to significant differences in respondents' purchase behavior of oranges based on carbon emission levels. Consumers belonging to a high EC group were willing to pay over 2.2 times higher than consumers in a low EC group for the reduction of 1g of CO_2 emissions per orange. Loureiro *et al.* (2002) measured American consumers' WTP for eco labeled apples using a double-bounded logit model. They used the eco-label certified by The Food Alliance, a non-profit third-party certifying organization based in Portland, Oregon. However, the mean premium for eco-labels was low, only 5% of market prices. This study indicates the importance of consumer's recognition of the labels. As presented at www.ecolabelindex.com, more than 150 institutes certify eco-labels on food. Although many eco-labels have been developed, only a few were recognized. Low accessibility to labels may lead consumers to place a low value on this information.

In South Korea, to the best of our knowledge, few studies have measured WTP for carbon labels on foods. According to survey results by KEITI, only one third of consumers in Korea indicated willingness to purchase products with carbon labels when the price was 5% higher than market prices (KEITI, 2009). Therefore, this study will measure Korean consumers' WTP for fresh apples produced ecologically. In particular, this study aims to measure the value of mandatory implementation of carbon labels.

4. Study framework and methodology

A framework of climate change perceptions and carbon labeling preferences

Previous carbon labeling studies focused on understanding consumers' attitudes and perceptions about climate change and measured WTP for carbon labels. This study asked, in what circumstance do consumers perceive GHG emission as an important attribute? The study tested whether consumers who perceive the effect of climate change on their lives would place greater value on the information on carbon labels. Connections between the two sectors will provide quantitative information about the value of GHG emission according to qualitative personal perceptions.

In a conditional logit model, invariant variables such as demographics and attitudes are implemented as interaction terms with attributes of the choices to avoid constant variations within the group. The number of estimated parameters is determined depending on the size of invariant variables and the number of attributes of the choices. As invariant variables and attributes that can be interacted with the invariant variables become larger, the model loses a degree of freedom. If an interesting invariant variable is not exogenous, the interaction terms violate the assumption that covariates are exogenous in the population. The instrument variable (IV) estimate is an appropriate method to figure the issues in general applications. However, the IV estimate is complicated to use when there are multiple endogenous variables from interactions with an endogenous invariant variable. Also, the duplications of observations lead to invalid standard errors of the IV estimation. Therefore, we used two-step approaches using ordered logit models and conditional logit models, as described in Figure 2.

Figure 2 frames the modeling of individuals' perceptions of climate change and apple purchases based on various grades, prices and carbon labels. The probability that respondents agreed or strongly agreed that climate change influenced their personal lives was calculated based on the switched signs of marginal probability and the differences of marginal effect. The predicted probability was included in the apple purchase model as interactions with carbon labels. The interaction terms indicate preferences for carbon labels of individuals who perceived the impact of climate change on their personal lives.

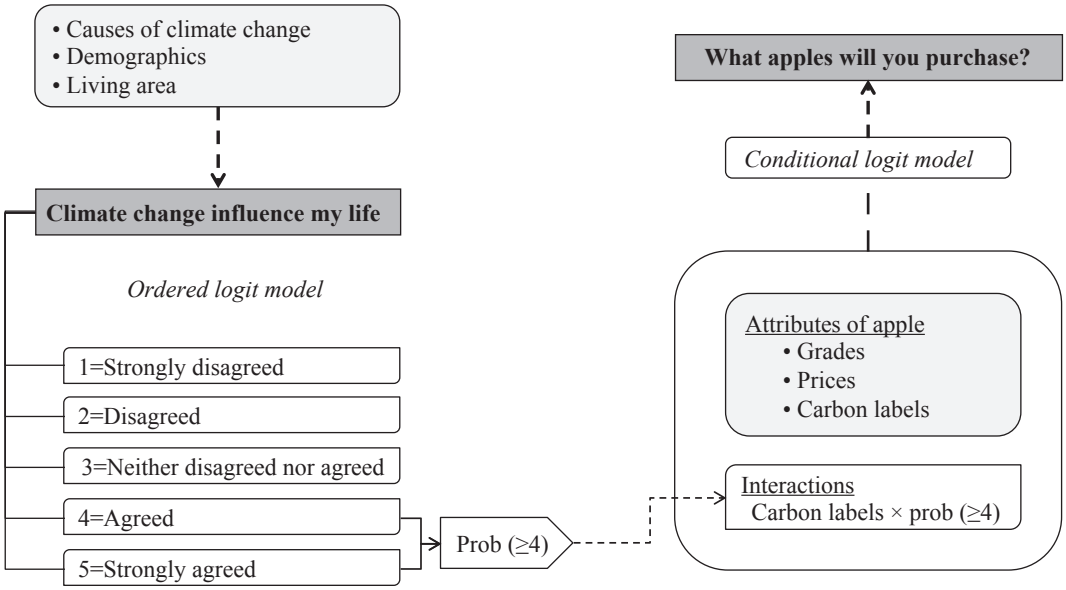

Figure 2. Modeling perception of climate change and apple purchases.

Application of ordered logit model for climate changes and personal lives

Participant perceptions about the impact of climate change on their personal lives were measured with 5-point scales (1 was strongly disagree and 5 was strongly agree, J=5). For convenience, define *W* as respondents' characteristics such as age, gender, income, education, residency (Seoul or not) and attitudes about human activity being the cause of climate change. From the estimated ordered logit model, we will have (J-1) unknown thresholds (α_j) and regression parameters (β) associated with *W*.

$$Y^* = \sum_{j=1}^{J-1} \alpha_j + W'\beta + \varepsilon;\ Y = \sum_{j=1}^{J} j\, I\,(\alpha_{j-1} < Y^* \leq \alpha_j) \tag{1}$$

where *Y** is the latent variable measuring individuals' perceived impact of climate change on their personal lives, and *Y* is the indicated ordered response. The thresholds α_j are cut-points on the latent variable used to differentiate changing points given that all the predictor variables are set at zero. The sign of the regression parameter β can be immediately interpreted as determining whether or not the latent variable increases with the regressor. The corresponding estimated thresholds (α_j) and linear combination of between estimated parameters and variables ($W'\beta$) enter the ordered logit model with *j* indicating the five perception levels to obtain predicted probability:

$$\text{Prob}\,(Y \leq j|W) = \frac{\exp\,(\alpha_j + W'\beta)}{1 + \exp\,(\alpha_j + W'\beta)} \tag{2}$$

$$\text{Prob}\,(Y > j|W) = 1 - \text{Prob}\,(Y \leq j|W) \tag{3}$$

Applications of conditional logit model for effect of climate change on carbon labels

The experiments are based on random utility theory and are consistent with Lancaster's theory of utility maximization which states that consumers demand attributes embodied in a good (Louviere *et al.,* 2000). Let U_{ik} be the i^{th} individual's utility of choosing k^{th} alternative. The total utility can be divided into two components of a systematic component, V_{ik}, and a random component, ε_{ik}: $V_{ik} + \varepsilon_{ik}$. To indicate invariant variables and attributes of choice, the system component can be expressed: $V_{ik} = \alpha' X_{ik} + \beta_k' Z_i$ where X_{ik} is a vector of alternative attributes for individual *i* and Z_i is a vector of interaction terms between product attributes and individual characteristics.

A conditional logit model was estimated using CE information. Assuming the random component is independently identically distributed with type I extreme value (Gumble) distribution leading to a logit model formulation (McFadden, 1974). The probability of consumer *i* choosing alternative *k* out of *K* options is:

$$\text{Prob}\,(i=k) = \frac{\exp(V_{ik})}{\sum_{k=1}^{K} \exp(V_{ik})} \tag{4}$$

The systematic component includes five dummy variables, superior quality, good quality, CEC, LCPC and mandatory low-carbon certification (MLCC) of product attributes and prices. We set marketable quality and no carbon labeling as baselines. Also, the model includes three interactions between individuals' perception of the impact of climate change on their personal lives and three carbon labels. Based on signs and degree of marginal effect of each level, we used the predicted probability of agreeing and strongly agreeing to the statement as an indicator of respondents' attitudes about climate change. The systematic component model also includes a constant specific to the alternative 'None of these' to capture the average effect on utility when consumers do not purchase. The model was estimated using maximum likelihood estimation. From

estimated parameters, consumers' WTP was calculated with the negative of the ratio of attribute coefficients to price coefficients indicating the marginal rates of substitution (Louviere *et al.,* 2000).

5. Consumer survey of climate change and carbon labels

A consumer survey was conducted with primary shoppers in households living in urban areas in South Korea. The survey questionnaire was designed for face-to-face interviews and consisted of three parts. In the first part, participants were asked to indicate their perception and attitude toward climate change. In the second part, participants indicated their socio-economics, gender, age, level of education attained, income and living area. In the third part, participants were presented a panel explaining the definition and purpose of carbon labeling, including the current voluntary system and what the mandatory system could be. The panel did not describe other benefits of the mandatory carbon labeling system. Participants' self-evaluation of the benefits of a mandatory system will be reflected on purchase decisions in CE questions. Lastly, participants faced six CE questions.

We designed the CE using three attributes of fresh apples: price, quality and carbon labeling to measure WTP for apples. Four price levels represent retail prices for 5 kg of Fuji apples (the most popular size) depending on the quality: ₩ 20,000, ₩ 30,000, ₩ 40,000 and ₩ 50,000[1]. South Korea grades quality standards of fresh apples with three classes depending on external (size, shape, color, etc.) and internal (sweetness, juiciness, etc.) attributes: superior, good and marketable quality. A market price range of good quality apples was from ₩ 25,000 to 46,000 in 2012, based on the price information provided by the Korea Agro-Fisheries and Food Trade Corp. Two levels of current carbon labeling (CEC and LCPC) and a MLCC were included in the choice experimental design, which also included a no carbon labeling baseline.

A large number of hypothetical apples could be constructed to make two alternatives using three attributes and their various levels. Based on a D-efficiency criterion, 144 alternatives provided 100% efficient design. Despite the high efficiency, the number of designs will create many different versions of survey questions. The number of choice sets is related to quality of information (Johnson and Orme, 1996) and participants' burden to respond. Optimal profiles of the attributes were drawn using an orthogonal design, from which 36 profiles were obtained, which achieved a D-efficiency score of 98.6. Although this number is significantly reduced, the 36 profiles are still a large number to evaluate because the respondents also answer other questions[2]. The 36 profiles were randomly sorted into six blocks, as shown in Supplementary Table S1. Six versions (one with each block) were randomly distributed to respondents. In each choice set, respondents will select one of two hypothetical apples or select a 'None of these' option, as shown in Table 2. This feature ensured that respondents were never forced to purchase an apple. Following the pre-test, respondents spent 15 to 20 minutes to complete the final questionnaire.

The survey was conducted by trained interviewers in Daegu, which is the third largest city of six metropolitan cities in Korea, and in Seoul, which is the capital and the biggest city in Korea, in August 2012. We recruited

[1] The average exchange rate in August of 2012 was used to convert the unit (₩ 1,133 = 1 US$).
[2] Orme (2006) indicated the importance of appropriate choice tasks to obtain reliable answers. Johnson and Orme (1996) found no evidence of increasing random error within about 20 choice tasks.

Table 2. A translated question example from the choice experiment.

	Apple 1	**Apple 2**	**none of these**
Grade	good	superior	
Carbon labels	mandatory low carbon certification	Carbon emission certification	
Price	₩ 40,000/5 kg	₩ 30,000/5 kg	
I would choose…	□	□	□

eight interviewers who were college students with experience in consumer surveys and trained them to understand the purpose of the study, interview skills about choice experimental questions and to explain the carbon labeling system. A pretest with trained interviewers was conducted for two days, August 23 and 24, 2012. After pretest, the questionnaire and survey procedures were finalized. The interview was conducted in randomly selected grocery stores and respondents were also randomly selected from the selected grocery stores. Of 280 consumers initially requested to participate the survey, we obtained 186 valid observations providing a 6.9% of margin of error under 5% significance levels using stratified sampling without replacement.

6. Sample descriptions and attitudes toward climate changes

A summary of respondents' demographic characteristics are shown in Table 3 alongside census data. Average age of respondents was very close to the census, while respondents were more likely to be female, educated and residents of Seoul compared to the census. Since the target samples were primary shoppers in households, the high percentage of female respondents was acceptable. To improve representation of certain groups in the population, we used post-stratification weights to adjust the distribution gaps of education and residency.

Respondents' average attitudes toward climate change are shown in Table 4. The majority of respondents felt the effect of climate change in their lives. Over 57% of respondents agreed (strongly agree or agree) that climate change affected their personal lives. This implies that climate change is not only a national issue, but a private issue. Over 60% of respondents indicated a major cause of climate change is human activity, compared to natural causes. Many individuals indicated willingness to change their behavior and activities to reduce climate change (about 78%). However, over 60% of respondents pointed out that there are many external factors which make their effort difficult. Overall, approximately 90% of respondents agreed that efforts to reduce climate change are very urgently required and 91% indicated that they strongly concerned or concerned climate change. This finding is very similar to the study result from the Ministry of Environment that has showed over 90% of consumers were concerned climate change and perceived the conditions as serious (Ministry of Environment, 2007, 2008)[3]. To reduce climate change, about 87% of respondents agreed to reduce consumption of products which cause environmental pollution and about 55% of respondents indicated that they would pay more for products which reduce climate change.

[3] We calculated statistical power using the answers of respondents' concerns about climate change compared to the result of national study conducted by the Ministry of Environment (2007) in order to alleviate concerns about the sample size. The power of the study is 0.9656 indicating that the probability of rejecting the null hypothesis while the alterative hypothesis is true was over 96% given the sample size.

Table 3. Sample descriptive statistics and variable description.

Variable	Variable description and code[1]	Sample n=186	Seoul n=107	Daegu n=79	South Korea Census[2]
average age	respondent age	39.9	42.2	36.7	38.9
gender (%)	1 if male	32.3	34.6	29.1	50.1
income (%)	1 if monthly household income was ₩ 4 million and over	51.6	53.3	49.4	40.0
education (%)	1 if respondents completed 2 yr or 4 yr college	75.8	71.0	82.3	51.8
Seoul (%)	1 if respondents live in Seoul	57.5	100.0	0.0	43.5[3]

[1] Alternative code for the dummy variables, gender, income, education and Seoul is '0'.

[2] All census statistics are based on 2012.

[3] Percentage of population living in Seoul of seven metropolitan cities in 2012.

Table 4. Attitudes about climate change.

Variable	Variable description and code[1]	Sample (%) n=186	Seoul (%) n=107	Daegu (%) n=79
climate change	5 if respondents strongly agreed that climate change influence my daily life	6.5	9.4	2.5
	4 if respondents agreed	51.1	58.9	40.5
	3 if respondents neither agreed nor disagreed	25.3	28.0	21.5
	2 if respondents disagreed	16.1	3.7	32.9
	1 if respondents strongly disagreed	1.1	0.0	2.5
human	1 if respondents believed a major cause of climate change is human activity not natural causes change	60.2	66.4	51.9
behavior	1 if respondents will change their behavior and activities to reduce climate changes.	77.9	85.9	67.1
extra factors	1 if respondents perceived that there are extra factors which make their effort difficult.	62.9	65.4	59.5
effort	1 if the effort to reduce climate change is urgent.	88.7	91.6	84.8
consumption	1 if I will reduce consumption of products which cause environmental pollution to reduce climate change.	88.7	90.7	86.1
pay more	1 if I will pay more to purchase products which reduce climate changes.	56.9	56.1	58.2
concerns about climate change	1 if respondents strongly concern or concern about climate changes	90.9	92.5	88.6

[1] Alternative code for the dummy variables is '0'.

7. Estimated results and discussions

The results of the estimated ordered logit models performed with survey data in Stata® 13 (StataCorp, College Station, TX, USA) are shown in Table 5. Looking at differences among demographics, perceptions of the impact of climate change on participants' personal lives were not significantly different by age and education, but the perceptions were significantly different by gender and income. Male respondents were less likely to feel the impact of climate change on their lives compared to female respondents. Respondents who earned over the average national household income were more likely to feel the impact of climate change on their lives. Aside from demographics, respondents' living area was significantly different from zero at the 5% level. Participants living in Seoul were more likely to perceive the impact of climate change on their lives. This result suggests that people living in Seoul were influenced by environmental concerns and is also consistent with the different levels of environment issues by region (Lee *et al.*, 2011). Although respondents who believed human activities are a major source of climate change were more likely to perceive the impact of climate change on their lives, the estimated parameter was not significant. The result indicates that causes of climate changes are not major factors explaining perceptions of the impact of climate change on respondents' personal lives.

Marginal effects of variables are shown in the last five columns of Table 5. The marginal effects indicate the change of probability for a particular answer given a one unit change of a covariate. For the statement of the impact of climate change on their personal lives, male respondents were 10.9% more likely to disagree than females, and respondents living in Seoul were 18.8% less likely to disagree than respondents living in Daegu. The signs of marginal effects changed at the level that respondents agreed to the statement that climate change influences their personal lives (j=4). In addition, the biggest difference in marginal effect occurred between the third and fourth level. Respondents living in Seoul were 33% (sum of marginal probability of 'agree'

Table 5. Estimated results of likelihood of climate change impacting daily lives.[1]

	Coefficient	Std. err.	Marginal effect				
			P **(Y=1)**	***P*** **(Y=2)**	***P*** **(Y=3)**	***P*** **(Y=4)**	***P*** **(Y=5)**
age	0.027	0.017	0.000	-0.003	-0.003	0.005	0.001
gender	-0.789**	0.347	0.005	0.109**	0.079**	-0.160**	-0.032**
income	0.555*	0.331	-0.003	-0.070	-0.060*	0.109*	0.025
education	-0.540	0.401	0.002	0.062	0.062	-0.098	-0.028
Seoul	1.380**	0.349	-0.009	-0.188**	-0.131**	0.267**	0.061**
human	0.484	0.386	-0.003	-0.063	-0.052	0.097	0.021
cut1	-3.474**	1.058	–				–
cut2	0.078	0.864					
cut3	1.419	0.901					
cut4	4.763**	1.004					
n			186				
F(6, 180)			6.26 (*P*-value<0.05)				

[1] ** and * indicate that the coefficients are significantly different from zero at 5% and 10% levels, respectively.

and 'strongly agree') more likely to perceive the impact of climate change on their lives than respondents living in Daegu. Also, male respondents were 19% (sum of marginal probability of 'agree' and 'strongly agree') less likely to perceive the impact than female respondents.

We calculated the predicted probability of individuals' perception of the impact of climate change on their personal lives for agreeing or strongly agreeing to the statement, Prob (Y≥4) because the changes of marginal effect were not only the greatest between the Likert scales of 3 and 4, but the effect sign changes at this point. Figure 3 includes the distribution of the predicted probability by respondents' living area. The mean of predicted probability is 57.0%, ranging from 11.9 to 92.2%. That is, on average, 57.0% of individuals perceived the impact of climate change on their personal lives. However, the bimodal distribution of predicted probability indicates that consumer perception of the impact of climate change on their personal lives was polarized and the average does not appropriately represent the whole distribution. Overall, respondents' living area explained much of the distinction. Therefore, we will compare consumers' WTP at the lower quartile (Q1=36.8%, i.e. 25th percentile) and upper quartile (Q3=77.6%, i.e. 75th percentile) of the distribution to represent two areas, along with the average in the second stage. The lower and upper quartiles also represent the average predicted probability for respondents who lived in Seoul (72%) and who lived in Daegu (37%).

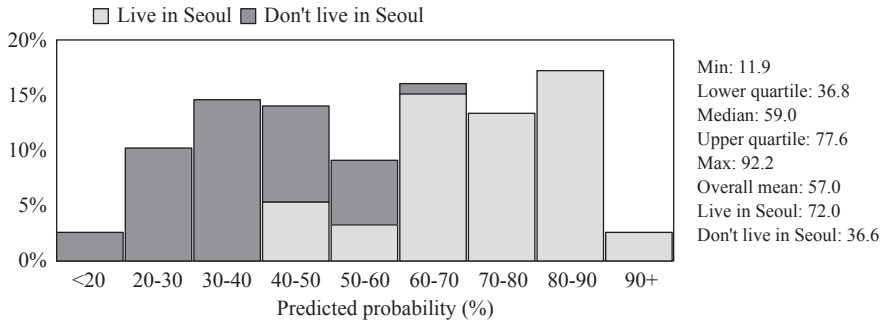

Figure 3. Distribution of predicted probability by respondent's living area, *P*(Y≥4).

The estimated results of the conditional logit model are shown in Table 6[4]. The sign of an alternative specific constant indicated respondent utility decreased when they selected not to purchase apples. All estimated parameters were statistically significant at 10% or less and have expected signs, positive for quality and carbon labeling, and negative for prices. This indicates that the attributes are important factors when consumers purchase apples. That is, higher quality apples and products with carbon labels were preferred, while expensive apples were not preferred. Also, all signs of the interactions were positive, which indicated that consumers who perceived the impact of climate change on their personal lives were more likely to select products with carbon labels or produced in an environmentally friendly way, compared to respondents who did not. In other words, consumer perception about climate change is an important factor for the success of low carbon labels.

To compare consumer utility levels in monetary terms, WTPs for carbon labels were calculated as a ratio of attribute coefficients to price coefficients, as shown in the last column of Table 6. Standard errors were measured with the delta method. The values for carbon labels were compared to no carbon labels and the changes of WTPs over probability were also specified. Higher levels of WTP reveal higher utility levels for consumers when they consume the products. As the probability that consumers perceived the impact of climate change on their personal lives increased, WTPs for carbon labels increased. In particular, the gap between voluntary and MLCC increased as the probability that consumers perceived the impact of climate change on their personal lives increased. At the mean of the predicted probability ($\overline{P}$=57.0), an average WTP for a carbon emission certification was ₩ 14,894/5 kg (about 43% of average market price, ₩ 35,000/5 kg), an average WTP for a low carbon product certification was ₩ 20,234/5 kg (about 58% of average market price), and an average WTP for MLCC was ₩ 23,429/5 kg (about 67% of average market price).

As pointed out above, the lower and upper quartiles represent average predicted probability of respondents' perception about climate change by living area. The predicted probability of respondents living in Seoul was highly distributed in the upper quartile and of respondents living in Daegu was mostly distributed in the lower quartile. Consumers who were in the upper quartile of predicted probability were willing to pay ₩ 3,916~6,455/5 kg more for carbon labels than consumers in the lower quartile of predicted probability. As the carbon labels are restricted, the differences of WTP between the lower and upper quartiles are larger.

[4] We considered the random parameters logit model but we did not find significant heterogeneity of individuals.

Table 6. Estimated results of conditional logit model and willingness to pay for carbon labels.[1,2]

	Coefficients	**Std. err.**
ASC	-4.635**	0.320
good quality	1.136**	0.155
superior quality	1.872**	0.174
CEC	1.188**	0.453
LCPC	1.762**	0.440
MLCC	1.817**	0.498
price	-0.00013**	0.000
P(Y≥4)×CEC	1.210*	0.734
P(Y≥4)×LCPC	1.384*	0.731
P(Y≥4)×MLCC	1.995**	0.836
LR χ^2 (10)	1,432.39	*P*-value<0.05
log likelihood	-509.858	

Willingness to pay for carbon labels by quartiles (₩/5 kg)			
	Lower quartile (Q1)	$\overline{P}$[3]	**Upper quartile (Q3)**
CEC	12,956**	14,894**	16,872**
	(1,882.16)	(1,501.97)	(1,941.49)
LCPC	18,018**	20,234**	22,495**
	(1,817.25)	(1,563.08)	(2,100.44)
MLCC	20,234**	23,429**	26,689**
	(2,076.32)	(1,777.71)	(2,385.46)

[1] ** and * indicate that the values are significantly different from zero at 5% and 10% levels, respectively.

[2] ASC = Alternative specific constant; CEC = carbon emission certification; LCPC = low carbon product certification; MLCC = mandatory low-carbon certification.

[3] Mean of predicted probability of consumers perceived the impact of climate change on their personal lives.

The marginal WTPs and confidence intervals by quality levels and carbon labels measured with the delta method are shown in Table 7. Consumers were willing to pay about ₩ 9,011/5 kg extra to purchase good quality apples instead of apples that were marketable quality. To purchase superior quality, consumers were willing to pay an extra ₩ 5,837/5 kg over good quality. Differences of market price between good quality and marketable quality were, on average, ₩ 6,798 to 10,197/5 kg in 2012 and 2013, respectively (Korea Agricultural Marketing Information Service: www.kamis.co.kr). The marginal WTP, ₩ 9,011/5 kg, was within the boundary of the difference of market prices. Average respondents were willing to pay an extra ₩ 5,339/5 kg to purchase apples with reduced carbon emission (i.e. LCPC) labels rather than carbon measured (i.e. CEC). When the low carbon labels were mandatory (MLCC), they were willing to pay an extra ₩ 8,534/5 kg to purchase apples produced with low carbon emission compared to carbon emission certification. In addition, marginal WTPs at the upper quartile were greater than those at lower quartile.

The significance of the marginal WTPs varies depending on the probability of respondents perceiving that climate change impacts their personal lives. Figure 4 includes marginal WTP for carbon labels across the predicted probability of the effect of climate changes on personal lives. The shaded area indicates significant marginal WTP. Marginal WTPs from carbon emission certification to low carbon product certification were significant, with the predicted probability ranging from 19 to 100%. Approximately 98.4% of respondents were in this range. Marginal WTPs from low carbon emission certification to MLCC were significant, with the predicted probability ranging from 44 to 100%. Approximately 68.3% of respondents were in this range. As consumers perceived the effect of climate change on their lives, consumers significantly preferred MLCC to voluntary low carbon certification. This implied that consumers were ultimately interested in the

Table 7. Marginal willingness to pay.[1]

	Marginal WTP (95% confidence interval), $/5kg		
	Lower quartile	**Average**	**Upper quartile**
By apple grades			
marketable to good quality	–	9,011** (6,773~11,258)	–
good to superior quality	–	5,837** (3,411~8,264)	–
By carbon label levels[2]			
CEC to LCPC	5,062** (1,110~9,014)	5,339** (2,240~8,439)	5,623** (1,214~10,032)
LCPC to MLCC	2,217 (-1,256~5,689)	3,195** (597~5,793)	4,193** (520~7,867)

[1] ** indicates that the values are significantly different from zero at 5% levels.

[2] WTPs are given in South Korea Won. On average, exchange rates were ₩ 1,133 = 1US$; August 2012.

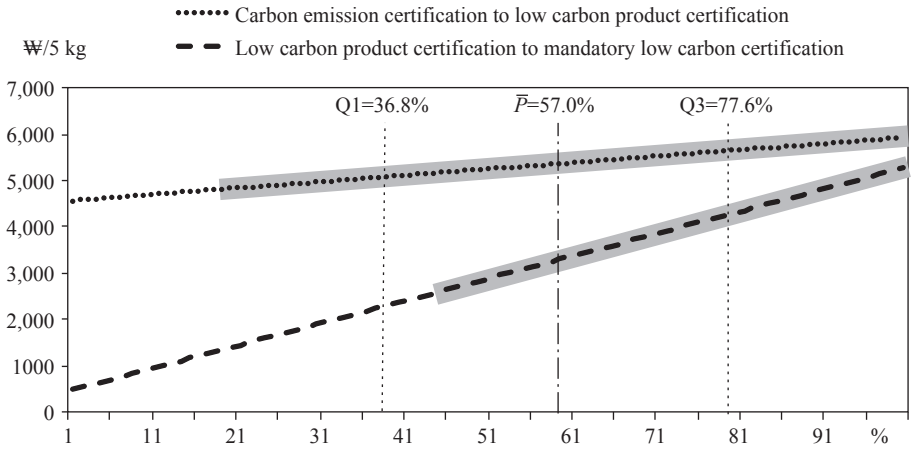

Figure 4. Marginal willingness to pay for carbon labels by probability levels.

reduction of carbon emission to alleviate the impact of climate change on their personal lives. In particular, consumers who live in a vulnerable area to climate change significantly preferred not only reduction of carbon emissions to certification of carbon emission but mandatory low carbon labels.

The premium for carbon certification and low carbon labels from this study was 30~40% in the lower quartiles and 43~54% in the upper quartiles of the predicted probability. The dispersion (quartiles) of the predicted probability of the impact of climate change on their personal lives was closely related to respondent living area (Figure 3) and levels of environmental disorder or air pollution. One critical environmental disorder in South Korea is increasing air pollution. In particular, increasing concerns about particulate matter (PM) stimulate consumers to fear for the air safety. Noll *et al.* (2007) and Vogt *et al.* (2011) found a positive relationship between carbon emission and PM. The negative impact of PM on human health has been reported (Dockery and Pope, 1994; Englert, 2004; Harrison and Yin, 2000) and the United States Environmental Protection Agency also warns of the potential health problems of PM for human lungs and heart (U.S. EPA, 2004). Jang *et al.* (2012) found that the level of PM_{10} varied by geographical area in South Korea: of 10 major cities, Seoul ranked the third highest in PM_{10} levels. Consumers who live in Seoul breathed PM_{10} at least 30 days (about a month) per year between 2001 and 2008 (Lee *et al.* 2011). Because of the nature of air pollution, these people may strongly feel the necessity of curbing environmental disorder and place a high evaluation on the low carbon labels, much as if they represent a private attribute.

8. Conclusions

Voluntarily implemented carbon labels have not appeared to lead companies to develop technology to reduce carbon emissions. To improve the effect of carbon labels, making low carbon labels mandatory has been suggested. A prior condition to the success of the program is consumer value for carbon labels. Although previous studies have found positive consumer value for products with low carbon emission labels, the carbon labels seem to play a less important role in consumer's decision making in the real market. This study has focused on investigation of factors that would influence consumers' value for carbon labels along with individual perceptions about the impact of climate change on their personal lives.

Based on a consumer survey with CEs, this study compared consumer preferences between mandatory and voluntary carbon labels while considering individuals' perceptions of the impact of climate change on their personal lives. An ordered logit model was used to measure the probability of perceptions about the impact of climate change on individuals' personal lives. The predicted probability was implemented in a conditional logit model to measure consumer preference for carbon labels based on levels of perception.

This study showed that consumers in South Korea generally recognized climate change in their lives and perceived the necessity of some effort to reduce climate change. Also, consumer perceptions about the impact of climate change on their personal lives was an important indicator to predict the success of carbon labels in the market. Respondents who more perceived the impact of climate change on their personal lives (at upper quartile, 77.6%) were willing to pay ₩ 561~2,538/5 kg extra to purchase the same apples with low carbon emission labels as compared to respondents who weakly perceived the impact of climate change (at lower quartile, 36.8%). Consumers who were more exposed to the risk of environmental disorder tended to significantly prefer mandatory low carbon emission labels and strongly feel their impact. In this study, we found that consumers' living area played a crucial role. In other words, consumers living in a vulnerable area to climate change had high value for low carbon emission labels and mandatory low carbon emission labels.

A limitation of this study is the relatively small sample size and underrepresented distribution of respondents' education levels and living area. Although the margin of error located an acceptable range, the statistical power of the survey is high and post-stratification was used for adjusting sample distribution, the concerns about the sample still remain. Future research could investigate consumer perceptions of mandatory versus voluntary labels both in Korea with a larger sample size, as well as other countries to further our understanding of this topic.

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2015.0095.

Table S1. Profiles of hypothetical apples.

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