Consumer Valuations of Beef Steak Food Safety Enhancement in Canada, Japan, Mexico, and the United States

Glynn T. Tonsor,[1] Ted C. Schroeder,[2] Joost M. E. Pennings[3] and James Mintert[4]

[1]*Assistant Professor, Department of Agricultural, Food, and Resource Economics, Michigan State University, 317-B Agriculture Hall, East Lansing, MI 48824 (corresponding author: phone: 517-353-9848; fax: 517-432-1800; e-mail: gtonsor@msu.edu).*
[2]*Professor, Department of Agricultural Economics, Kansas State University, 219 Waters Hall, Manhattan, KS 66506 (phone: 785-532-4488; fax: 785-532-6925; e-mail: tcs@ksu.edu).*
[3]*Associate Professor, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, and the AST Professor of Marketing & Decision Sciences at Wageningen University, Tongersestraat 53, Room B1.13, 6211 LM Maastricht, The Netherlands (phone: +31-43-388-3934; fax: +31-43-388-4875; e-mail: joost.pennings@finance.unimaas.nl, jme.pennings@mw.unimaas.nl).*
[4]*Professor, Department of Agricultural Economics, Kansas State University, 218 Waters Hall, Manhattan, KS 66506 (phone: 785-532-1518; fax: 785-532-6925; e-mail: jmintert@ksu.edu).*

Food safety concerns have had dramatic impacts on food and livestock markets in recent years. We examine consumer preferences for beef steak food safety assurances. We evaluate the extent to which preferences are heterogeneous within and across country-of-residence defined groups and examine the distributional nature of preferences with respect to marginal improvements in food safety. Using mixed logit models, we find that consumers in Canada, Japan, Mexico, and the United States have willingness to pay preferences that are nonlinear in the level of food safety risk reduction. In particular, consumers in Japan and Mexico have preferences that are convex and consumers in Canada and the United States have preferences concave in the level of food safety enhancement.

Les inquiétudes entourant la sécurité alimentaire ont eu des répercussions considérables sur le marché du bétail et le marché des aliments au cours des dernières années. Nous avons examiné les préférences des consommateurs concernant l'assurance de la sécurité alimentaire de la viande de bœuf. Nous avons évalué dans quelle mesure les préférences des consommateurs étaient hétérogènes au sein de groupes établis selon le pays de résidence et entre ces groupes, et avons examiné la nature distributionnelle des préférences à l'égard des améliorations marginales de la sécurité alimentaire. L'utilisation de modèles logit mixtes nous a permis d'établir que la volonté de payer des consommateurs du Canada, du Japon, du Mexique et des États-Unis étaient non linéaires lorsqu'il était question de diminuer le degré de risque concernant la sécurité alimentaire. Les préférences des consommateurs du Japon et du Mexique étaient convexes, tandis que celles des consommateurs du Canada et des États-Unis étaient concaves lorsqu'il était question d'accroître le niveau de sécurité alimentaire.

INTRODUCTION

Food safety is a growing global concern. Maintaining and gaining market access increasingly requires food safety assurances by food production and processing industries. Food safety management and regulation is receiving more direct involvement by government regulatory and inspection agencies and has gained considerable attention of policy makers. Consumers are demanding increased food safety assurances as even isolated food safety events have caused major market disruptions. Beef markets have been particularly adversely affected by food safety concerns in recent years. For example, discovery of a beef cow in Canada and later in the United States infected with bovine spongiform encephalopathy (BSE) in 2003 caused immediate and long-lasting closure of many major North American beef export markets. Regaining global market access has required changes in animal age verification, costly alterations to beef processing, product losses, and careful segregation of meat products (Coffey et al 2005). Intensive inspections coupled with zero tolerance for a variety of food safety-related concerns, have made it challenging to maintain market access, even with a host of added food safety protocols, regulations, and frequent audits.

Enhancing food safety requires increased food production, processing, and handling costs (Muth et al 2003). Therefore, before large investments in food safety protocols, policies, and inspections are made, more information is needed regarding probable return from these investments. That is, in order to determine appropriate investments in food safety management and monitoring, decision makers need to know, among many other things, how concerned consumers are about beef food safety, how much they will pay for additional food safety assurances, and the size of concerned consumer segments. Moreover, public policy formation can be improved by comprehension of consumer preferences and corresponding willingness to pay (WTP) for food safety improvements. Accordingly, the primary objective of this study is to estimate consumer valuation of food safety enhancements in beef steak. We focus on a single cut, beef strip steak, in our study for several reasons: (1) strip steak is a well-defined relatively homogeneous product consumed in each of the countries we study and thus needs little description to be recognized by consumers and it is easy for consumers to assign a value to the product, (2) it is a product often associated with North American grain fed beef, the focus of our study, and (3) the product can be more easily traced than comingled ground product from multiple animal and slaughter facility sources, making it easier to link to individual animals in food safety management.

This research focuses on increasing our understanding of similarities and differences in consumer perceptions and valuations for beef steak attributes in Canada, Japan, Mexico, and the United States. These four countries were, historically, the largest markets for North American beef. Food safety-related policies of these countries have impacts on consumers in each of the countries. Given markedly different reactions in these countries to beef food safety events, they warrant investigation regarding differences in preferences. The approach taken here provides an empirical measure of consumer heterogeneity in preferences within and across countries. The model relaxes common assumptions of homogeneous preferences and marginal utility of income. Furthermore, this project evaluates trade-offs of nonmonetary attributes with food safety, examines if food safety preferences are nonlinear in the level of risk reduction, and estimates the size of consumer markets likely to buy enhanced beef steak products having various premiums.

PREVIOUS RESEARCH AND OBJECTIVES

Research has documented a range of differences across counties in the challenges and approaches governments face in regulating food safety. Brewster and Goldsmith (2007) outline different approaches to food safety regulation of the United States and United Kingdom. They note that while resulting food systems may be equally safe, food safety regulations differ fundamentally. Batres-Marquez et al (2007) note that the Mexican government has encouraged livestock producers to use federally inspected slaughter plants through direct subsidies to producers. Dong and Jensen (2007) reveal China has struggled implementing sanitary and phytosanitary measures that meet demands of more developed countries. Zivin (2006) examined benefits of governments applying multiple food safety quality standards and found optimal standards to critically hinge on consumer perceptions of food safety risk. Ultimately a country's food safety regulatory environment reflects the sentiments of the countries consumers. Our work focuses on better understanding heterogeneous consumer demand for food safety reflective of diverse perceptions among consumers.

Several studies have investigated what consumers are willing to pay to avoid or obtain various food attributes (Misra et al 1991, 1997; Burton et al 2001; Grannis and Thilmany 2002; Lusk et al 2003; McCluskey et al 2003; Roosen 2003; Roosen et al 2003; Alfnes 2004; Tonsor et al 2005; Loureiro and Umberger 2007). Some of these studies considered consumers in multiple countries (Lusk et al 2003; Tonsor et al 2005). Moreover, a few studies have focused on consumer WTP for food safety assurances or risk reductions (Brown et al 2005; McCluskey et al 2005; Goldberg and Roosen 2007; Loureiro and Umberger 2007). Brown et al (2005) employed an experimental auction to value Canadian consumers' WTP for reductions in risk of becoming ill from exposure to *Campylobacter* from a chicken sandwich. Using Vickrey second price auctions, the authors found consumer WTP for lower *Campylobacter* risk to be decreasing functions of the individual's risk tolerance. Loureiro and Umberger (2007) used choice experiments to examine U.S. consumer preferences for beef steak attributes. The authors found U.S. Department of Agriculture food safety inspection to be valued more than country-of-origin, traceability, or tenderness assurances.

In a study among German consumers, Goldberg and Roosen (2007) used both contingent valuation and choice experiment methods to examine consumer WTP for reductions in *Salmonellosis* and *Campylobacter* risk. WTP estimates based upon choice experiment methods were highly convex in the level of each risk reduction. That is, WTP increased more than proportionally with risk reductions. In contrast, WTP values obtained from contingent valuation questions were subadditive. McCluskey et al (2005) examined Japanese consumer reluctance to exchange money for BSE-tested beef. Using choice contingent valuation methods, the authors' findings suggested that representative Japanese consumers were willing to pay a 56% price premium for BSE-tested beef.

Each of these studies contributes to our understanding of consumer perceptions of food safety risk in the meat industry. Our study extends previous work by allowing heterogeneous preferences across consumers, comparing consumers from different countries-of-residence, and utilizing a data collection method that allows consumers to reveal trade-offs between nonmonetary product attributes and food safety. In particular, heterogeneous preferences are evaluated (utilizing mixed logit models), in a multinational study that allows for cross-country comparisons important in understanding the international meat market complex. The employed choice experiment facilitates an evaluation of consumer willingness to trade food safety attributes for both monetary and nonmonetary traits. In addition, the derived model relaxes the common assumption of homogeneous marginal utility of income, allows empirical examination of nonlinearity in food safety preferences in the level of risk reduction, and is used to estimate the size of consumer markets likely to buy enhanced beef steak products priced with various premiums.

RESEARCH DESIGN: DATA COLLECTION AND CHOICE EXPERIMENT

This study uses a choice experiment to estimate WTP for beef steak attributes. Our sample, drawn from consumers in Canada, Japan, Mexico, and the United States, represents a broad sample of consumers. To collect information about consumer perceptions and preferences we conducted an online computer survey of consumers from households located in Canada ($N = 1{,}002$), Japan ($N = 1{,}001$), and the United States ($N = 1{,}009$). The same survey was conducted via in-person interviews in Mexico ($N = 993$). The Mexico surveys were completed in-person because of limited computer access and/or use among the general population in Mexico. The fact that the Mexican surveys were conducted in-person as compared to electronically, could introduce bias into these responses relative to the other three countries and this should be kept in mind as results for Mexico are interpreted. The survey was translated into French (primarily for use in Quebec), Spanish (for Mexico), and Japanese to accommodate different respondent languages across countries.

The surveys were conducted through TNS NFO, a global market research company. TNS NFO has a vast consumer panel, with more than 5 million individuals worldwide in their data bank. For our surveys, TNS NFO targeted the adult in each household most familiar with household food shopping habits. Target respondents were older than 18 years of age and overall came from a representative distribution of household income levels. Ranking and choice questions were presented in randomized order across respondents to reduce question ordering biases. All surveys were completed between late February and early March 2006.

In addition to sociodemographic information about each respondent, meat consumption habits, perceptions of food safety risk present when consuming beef, and a multitude of other factors were collected. Each respondent also completed a choice experiment designed to determine the amount consumers were willing to pay for various beef steak production, food safety, and product quality attributes. Combined, this information provides a comprehensive assessment of views and preferences of consumers from four different countries about beef steak attributes.

Choice experiments simulate real-life purchasing situations and permit multiple attributes to be evaluated, thus allowing researchers to estimate trade-offs among different alternatives (Lusk et al 2003). In our study, consumers were presented with a set of 21 simulated shopping scenarios, each of which involved choosing a preferred alternative from two beef strip loin steaks and a no purchase option.

Steaks were offered at four different price levels selected to be consistent with local retail prices. Representative retail strip loin prices for North American grain fed beef (i.e., not dairy beef, not grass fed, and not Wagyu) at the time the survey was conducted in each

Table 1. Steak product attributes and attribute levels evaluated in choice experiments

Product attribute	Attribute label
Country-of-origin	Canada Japan Mexico United States
Production practice	Approved standards Natural
Tenderness	Uncertain Assured tender
Food safety assurance	Typical Enhanced 40% Enhanced 80%

	Canada (CAN $/lb)	Japan (Yen/100 grams)	Mexico (Pesos/kg)	United States ($U.S./lb)
Price[a]	5.50	300.00	120.00	5.00
	9.00	600.00	190.00	8.00
	12.50	900.00	260.00	11.00
	16.00	1200.00	330.00	14.00

Note: [a]Prices differed by country to be consistent with local retail price ranges. Prior to deriving WTP estimates all prices were translated (using February/March 2006 exchange rates) to $US/lb equivalent units.

country were provided to us by Canadian Beef Export Federation marketing staff located in each country and confirmed by United States Meat Export Federation (Clayton 2006; Harada 2006; Pearson 2006; Ruiz 2006; Sakemoto 2006; Takemichi 2006). In addition to price, the steaks varied by country-of-origin, production practice, tenderness assurance, and food safety assurance (see Table 1). An orthogonal fractional design (Kuhfeld et al 1994) was used to select scenarios in which steak prices are uncorrelated, and which allows for identification of own-price, cross-price, and alternative-specific effects. This process also allows the choice experiment to be of reasonable size for survey participants. An example choice scenario included in the choice experiment is

Steak attribute	**Option A**	**Option B**	**Option C**
Price ($/lb)	$14.00	$11.00	Neither A nor B is preferred
Country-of-origin	United States	Canada	
Production practice	Natural	Natural	
Tenderness	Assured tender	Uncertain	
Food safety assurance	Enhanced 80%	Enhanced 40%	
I choose . . .			

Though the choice experiments were hypothetical in that they did not include actual money or actual steak products, our instructions specifically stated “It is important that you make your selections like you would if you were actually facing these choices in your retail purchase decisions." This statement was included as part of a "cheap-talk" strategy at reducing hypothetical bias by informing survey participants of the concept prior to conducting the choice experiment (Cummings and Taylor 1999; Lusk 2003). Furthermore, given that our principal interest is differences in marginal WTP amounts, we are less concerned with the hypothetical nature of our survey (Lusk and Schroeder 2004). Descriptions included in the choice experiments of the specific product attributes were:

Country-of-Origin refers to the country in which the cow was raised and includes Canada, Japan, Mexico, or the United States.

Production Practice is the method used to produce the cow where *Approved Standards* means the cow was raised using scientifically determined safe and government-approved use of synthetic growth hormones and antibiotics (typical of cattle production methods used in United States and Canada); *Natural* is the same as typical except the cow was raised without the use of synthetic growth hormones or antibiotics.

Tenderness refers to how tender the steak is to eat and includes *Assured Tender* that means the steak is guaranteed tender by testing the steak using a tenderness measuring instrument and *Uncertain* means there are no guarantees on tenderness level of the steak and the chances of being tender are the same as typical steaks you have purchased in the past.

Food Safety Assurance refers to the level of food safety assurance with the steak.

Typical food safety means the steak meets current minimum government standards for food safety. *Enhanced 40%* means measures have been taken to reduce risks of illness associated with food safety from consuming the product by 40% relative to typical. *Enhanced 80%* means measures have been taken to reduce risks of illness associated with food safety from consuming the product by 80% relative to typical.

While most existing food safety studies focus on one specific concern (e.g., *Campylobacter* by Brown et al (2005); *BSE* by McCluskey et al (2005)) our experimental design purposely focuses more generally on general food safety risk associated with beef steak because consumers face an array of potential hazards every time they consume a product. We cast a wide net over food safety risk because we were interested generally in actions the beef industry supply chain or policy makers might take to improve food safety and usually such actions affect a broad set of potential hazards (e.g., federal inspection, trimming, steam pasteurization, hazard analysis critical control point plans in production and processing, animal production techniques, and food preparation and handling methods) and may be implemented as mandatory regulation or voluntary industry practices.

We did not provide specific details to participants on the "measures taken" to ensure 40% and 80% reductions in food safety risks relative to standard practices because valuing particular techniques (e.g., federal inspection) was not our interest. This research design is consistent with our principal focus of evaluating how consumers respond to beef steak labeled to have 40% and 80% reductions in risks of illness from beef steak consumption. That is, we are more concerned with consumer valuations of steaks possessing these labels than in risk reduction techniques that might be used to assure particular labels.[1] As noted by a reviewer, direct food safety labels may not be appealing to some consumers. However, the most straightforward way to determine consumer WTP for food safety enhancement was to pose the question directly. If consumers reveal WTP for food safety enhancements as presented directly in our study, then a valuable area for future research is to determine what types of product labels might be most desirable to provide food safety enhancement perceptions to consumers. If consumers are not willing to pay for food safety enhancements as we presented them in our choice experiments, then consumers either are not concerned about food safety enhancements or the enhanced food safety assurance raised concerns in consumers' minds.

A total of 4,005 respondents completed the survey across all four countries. Summary data of selected demographic attributes of survey respondents are provided in Table 2. In Canada and Japan, male and female respondents were about equally split, whereas, in the United States and Mexico, females represent about 80% of respondents. Respondents in Canada, the United States, and Japan had an average age ranging from 42 to 49 years old whereas Mexican respondents were younger, averaging 31 years of age. Although respondents in Mexico are younger than in the other three countries, this is consistent with Census data on age distributions across these four countries (United States Census Bureau 2006).

Mexican respondents tend to have lower education and income levels than respondents from the other three countries, consistent with their younger age distribution. More than 20% of Canadian and U.S. respondents are categorized in the upper income level, whereas about 12% of Japanese and 11% of Mexican respondents are from their respective highest income categories.

Nearly all respondents are at least occasional beef consumers, but there is a lot of variability in the frequency of consumption. For example, more than 60% of respondents in Canada, Mexico, and the United States consume beef at least two to three times per week. This compares to just 30% of Japanese respondents consuming beef this often.

Developing effective supply chain management strategies and policies that deal with food safety requires sound understanding of what consumers know (or perceive) about food safety. Therefore, we asked a set of questions to inquire about the level of understanding of the presence, probable impacts of, and sources of information that consumers use as they assess beef food safety concerns. Table 2 includes a breakdown of responses to the question *How safe do you think beef steak is for your personal consumption?* Canadian and American respondents generally believe beef steak products are safe with nearly 90% indicating steak to be *Very Safe* or *Somewhat Safe* for personal consumption. Japanese and Mexican respondents perceive relatively higher-risk levels. For instance, over 10% of each population considers beef steak as *Somewhat Unsafe* or *Not at all Safe* compared to 3% for Canadian and American consumers.

RESEARCH METHOD: RANDOM PARAMETERS LOGIT AND WTP ANALYSIS

A random parameters logit (RPL) model (also known as a mixed logit) was used to determine consumer WTP for the various steaks attributes of interest. The RPL model is well documented in the literature and allows for random taste variation within the surveyed population, is free of the independence of irrelevant alternatives (IIA) assumption, and allows correlation in unobserved factors over time, thus eliminating three limitations of standard logit models (Revelt and Train 1998; Hensher and Greene 2003; Train 2003;

Table 2. Demographic variables and summary statistics of choice experiment participants

Variable	Definition	Canadian consumers	Japanese consumers	Mexican consumers	U.S. consumers
Gender	1 = Female; 0 = Male	0.52	0.49	0.80	0.83
	Total participants	1,002	1,001	993	1,009
Age	Average age in years	47.7	41.8	31.1	48.9
Education (Highest level completed)					
	1 = Less than high school graduate	1.70%	2.60%	31.01%	2.30%
	2 = High school graduate	30.40%	32.70%	16.72%	19.50%
	3 = Some college or technical (no bachelor's)	40.20%	25.40%	17.92%	38.80%
	4 = College bachelor's graduate	17.00%	33.70%	25.98%	25.40%
	5 = Post-college graduate	7.30%	2.90%	8.26%	13.80%
	No response	3.40%	2.60%	0.10%	0.30%
Household income					
	1 = Lower	10.20%	33.10%	35.70%	18.40%
	2 = Lower–middle	23.10%	21.10%	39.00%	17.90%
	3 = Middle	25.50%	21.20%	14.10%	14.60%
	4 = Middle–upper	19.20%	12.20%	11.30%	22.20%
	5 = Upper	22.10%	12.50%	0.00%	26.90%
Beef consumption frequency					
	1 = 4 or more times per week	12.38%	3.10%	21.55%	17.74%
	2 = 2–3 times per week	47.80%	26.97%	45.62%	45.39%
	3 = Once per week	18.46%	29.37%	21.75%	20.32%
	4 = 2–3 times per month	9.98%	22.28%	7.45%	8.72%
	5 = Once per month or less	6.99%	16.08%	2.42%	5.35%
	6 = Never	4.39%	2.20%	1.21%	2.48%
Beef consumption frequency and income combinations					
	At least weekly consumption & lower–middle income	24.48%	28.88%	65.42%	29.92%
	At least weekly consumption & middle to upper income	54.03%	30.22%	23.49%	53.68%
	Less than weekly consumption & low or lower–middle income	8.68%	25.80%	9.17%	6.46%
	Less than weekly consumption & middle to upper income	12.81%	15.11%	1.92%	9.94%
Perceived safety of beef steak for personal consumption (*Steak_Risk*)					
	Very safe	45.60%	3.60%	16.30%	45.80%
	Somewhat safe	44.20%	46.40%	50.50%	42.00%
	Neither safe nor unsafe	7.10%	36.90%	22.90%	8.60%
	Somewhat unsafe	1.80%	10.60%	8.20%	2.40%
	Not at all safe	1.30%	2.60%	2.20%	1.20%

Notes: The income groups have country-specific ranges: *Canada* (Canadian Dollars): 1: ≤ \$15,000, 2: \$15,000–\$34,999, 3: \$35,000–\$59,999, 4: \$60,000–\$79,999, 5: ≥\$80,000; *Japan* (Japanese Yen): 1: ≤2,000,000, 2: 2,000,000–3,999,999, 3: 4,000,000–5,999,999, 4: 6,000,000–7,999,999, 5: ≥8,000,000; *Mexico* (Mexican Peso): 1: ≤4,000–6,000, 2: 7,000–21,000, 3: 22,000–54,000, 4: ≥55,000; *United States* (U.S. Dollars): 1: ≤\$22,500, 2: \$22,500–\$39,999, 3: \$40,000–\$59,999, 4: \$60,000–\$89,999, 5: ≥\$90,000.

Hensher et al 2006). In the context of our study, the RPL is appealing for a number of reasons. First, some of the steak alternatives presented in our choice experiment are similar, possibly making the IIA assumption overly restrictive. Second, a growing amount of research suggests consumers possess heterogeneous preferences, so employing a model that allows for and evaluates preference heterogeneity is appropriate (Alfnes and Rickertsen 2003; Lusk et al 2003; Alfnes 2004; Tonsor et al 2005). Finally, the RPL model facilitates correlation in random parameters and hence a through evaluation of relationships in preferences across steak attributes.

Underlying the RPL model is the consumer's random utility (U), in which the utility of option j for individual i in choice situation t is described by

$$U_{ijt} = \lambda_i' x_{ijt} + \varepsilon_{ijt} \tag{1}$$

where x_{ijt} is a vector of observed variables, λ_i is unobserved for each individual and varies within the population with density $f(\lambda_i \mid \theta^*)$ where θ^* are the true parameters of this distribution, and ε_{ijt} is the stochastic error component independent and identically distributed over all individuals, alternatives, and choice situations (Revelt and Train 1998). As noted by Alfnes (2004), this describes a panel data model where the cross-sectional element is individual i and the time-series component is the t choice situations. The RPL model is estimated by simulated maximum likelihood, requiring specification of the probability of each individual's selections. Let $j(i,t)$ denote the alternative that individual i choose in period t. The unconditional probability of subject i's selections is given by (Revelt and Train 1998)

$$P_i(\theta^*) = \int \prod_t \frac{e^{\lambda_i' x_{ij(i,t)t}}}{\sum_j e^{\lambda_i' x_{ijt}}} f(\lambda_i \mid \theta^*)\, d\lambda_i \tag{2}$$

The model estimated specifies the systematic portion of the utility function (V_{ijt}) as

$$V_{ijt} = \boldsymbol{\alpha}'\mathbf{P}_{ijt} + (\boldsymbol{\beta}_\mathbf{i} + \boldsymbol{\gamma}'\mathbf{Z}_\mathbf{i})\mathbf{x}_{jt} \quad \forall j = A, B \tag{3}$$

$$V_{ijt} = 0 \quad j = C \tag{4}$$

where $\mathbf{P}_{ijt}$ is a 4×1 price vector; $\mathbf{Z}_\mathbf{i}$ is a 3×1 vector of individual i's characteristics ($Female_i$, $Education_i$, and $Steak\ Risk_i$ as defined in Table 2); $\mathbf{x}_{jt}$ is a 8×1 vector of steak attributes ($\mathbf{x}_{jt} = [Canada_{jt}, U.S._{jt}, Japan_{jt}, Mexico_{jt}, Natural_{jt}, Tender_{jt}, FoodSafety40_{jt}, FoodSafety80_{jt}]$, where $Canada_{jt}$, $U.S._{jt}$, $Japan_{jt}$, and $Mexico_{jt}$ are dummy variables equal to one if the beef steak is labeled as originating from Canada, the United States, Japan, or Mexico, respectively (0 otherwise), $Natural_{jt}$, $Tender_{jt}$, $FoodSafety40_{jt}$, and $FoodSafety80_{jt}$ are dummy variables equal to one if the alternative is labeled as being naturally produced, assured to be tender, has 40% enhanced food safety relative to standard practices, and has 80% enhanced food safety, respectively (0 otherwise)); and $\boldsymbol{\alpha}$, $\boldsymbol{\beta}_\mathbf{i}$, and $\boldsymbol{\gamma}$ are vectors containing 4, 8, and 24 parameters to be estimated, respectively.

The inclusion of four price parameters follows the example of Train and Atherton (1995) and relaxes assumptions of homogeneous marginal utility of income while maintaining fixed price parameters. More specifically, we identified four combinations (see Table 2) of consumers based upon binary segmentation of income and beef consumption frequency.[2] Therefore, one element of $\mathbf{P}_{ijt}$ in Equation (3) equals the price faced by individual i in choice situation t for option j corresponding to the combination of their income and beef consumption frequency.

Inclusion of additional consumer information is facilitated by interaction of $\mathbf{Z_i}$ with $\mathbf{x}_{jt}$. This allows us to determine if preference heterogeneity persists beyond typically observed factors (Revelt and Train 1998; Nahuelhual et al 2004). Furthermore, interaction with steak attribute variables results in derived WTP estimates being functions of the included individual characteristics, an approach more consistent with economic theory than many WTP approaches (e.g., Lusk et al 2003).

Given the objectives of this research, and to keep the model feasible for estimation, we specify all price and interaction variables to be fixed within each resident-based population and focus on heterogeneity in preferences for each of the eight steak attributes. That is, we allow $\boldsymbol{\beta}_i$ in Equation (3) to vary within each population. It is important to note that these random coefficients could be correlated (Train 1998; Scarpa and DelGiudice 2004). For instance, consumers who are especially concerned with food safety might also be concerned with country-of-origin. To investigate these important possibilities, we let $\boldsymbol{\beta}$ represent the vector of steak attribute coefficients and specify $\boldsymbol{\beta} \sim N(\overline{\boldsymbol{\beta}}, \Omega)$. The resulting coefficient vector is expressed as $\boldsymbol{\beta} = \overline{\boldsymbol{\beta}} + \mathbf{LM}$ where $\mathbf{L}$ is a lower-triangular Cholesky factor of $\boldsymbol{\Omega}$ such that $\mathbf{LL}' = \boldsymbol{\Omega}$, and $\mathbf{M}$ is a vector of independent standard normal deviates (Revelt and Train 1998; Hensher and Greene 2003). Upon estimation, evaluation of the individual elements in $\mathbf{L}$ allows for a better understanding of correlations in preferences across the steak attributes evaluated.

Coefficients themselves have little interpretive value in RPL models. However, relative combinations of select coefficients provide economically meaningful insights on consumer preferences. In particular, WTP for steak attributes can easily be calculated. Frequently (e.g., Nahuelhual et al 2004; Rigby and Burton 2005) mean WTP for respondents are calculated at mean valuations of model covariates (e.g., $\overline{\mathbf{Z}}$). However, this approach ignores the distribution of preferences around the mean of random parameters (i.e., elements of $\mathbf{L}$). To relax this strong assumption, as well as consider statistical variability in parameter estimates, we utilize simulation techniques consistent with Rigby and Burton (2005), Hensher and Greene (2003), and Hensher et al (2006). In particular, we specifically follow (see p. 620) Hensher et al (2006) to consider both the entire distribution of WTP (rather than just mean and standard deviation) and statistical variability in parameter estimates. While additional details are available from Hensher et al (2006, p. 620), our application of this procedure essentially requires making 1,000 draws of the model parameters followed by 1,000 drawings, from each parameter vector draw, to capture heterogeneous preferences. Stated differently, the first 1,000 draws reflect statistical variability and the second 1,000 draws captures preference variability. Desired statistics (e.g., mean, proportion greater than a particular \$premium/lb) and corresponding confidence intervals are easily identified.

The simulated WTP statistics are utilized to empirically test for differences in WTP preferences. First, mean WTP estimates and 95% confidence intervals are identified that incorporate both statistical and preference variability. Second, a combinational technique suggested by Poe et al (2005) is used to provide a simple nonparametric evaluation of differences in WTP distributions. The difference between two simulated WTP series is evaluated with this difference being calculated for all possible combinations of the two series. In other words, 1,000,000 (1,000 × 1,000) differences (e.g., $WTP_a - WTP_b \; \forall a, b$; where $a = 1, \ldots, 1{,}000$ and $b = 1, \ldots, 1{,}000$) are calculated for each test. The proportion of simulated differences less than zero represents the probability that $WTP_a < WTP_b$. This combinational approach is more precise than simply evaluating if the 95% confidence intervals previously mentioned overlap (Poe et al 2005).

Industry participants and regulators need information beyond knowledge of preferences of the "average" consumer. Decision making can be notably enhanced with sound understanding of the proportion of a consumer population likely to purchase a given steak product at different price premiums. For instance, if the cost of reducing food safety risk by 40% falls from $5.00/lb to $2.50/lb and there are no changes in markup over costs, how many more consumers would be willing to purchase steak labeled to have a 40% reduction in food safety risks? The simulation procedures provide us with a simple way to answer this, and related questions. In particular, we estimate the proportion (and accompanying 95% confidence intervals) of respondents having WTP premiums of at least $0.00, $2.50, $5.00, $7.50, and $10.00. More specifically, the simulation procedure produces a series of 1,000 estimates for the portion of the population willing to pay each premium. From this series, we identify the mean proportion and use the 2.5 percentile and 97.5 percentile values to construct 95% confidence intervals.

RESULTS

Prior to settling on the random utility model as specified in Equations (3)–(4), an array of alternative model specifications were considered. While the multitude of model specification tests is not presented here for brevity; log likelihood tests consistently reject the hypothesis that preferences are jointly homogeneous or uncorrelated and the hypothesis that the consumer characteristic interaction terms are jointly insignificant. Overall, model fit of the utilized models (Table 3) was strong and consistent with other applications of RPLs (e.g., Lusk et al 2003).[3]

Estimated models result in negative estimates for all the fixed price coefficients, except for infrequent beef consumers with high incomes in Mexico. For this group, which comprises less than 2% of our Mexican sample (Table 2), the price coefficient is not statistically different from zero implying this consumer segment is price insensitive. The most price sensitive consumers in Canada, Mexico, and the United States consume beef at least once per week and have relatively high household incomes. In contrast, the most price sensitive consumers in Japan are those who consume beef less than once a week and have low income. The least price sensitive group in all four countries is the segment of consumers who eat beef less regularly and have higher incomes. Approximately, 60% (Japan) to 88% (Mexico) of the consumers in each country indicated they consume beef at least once per week (Table 2).

A majority (23/32) of the estimated means for the random steak attribute parameters across the four models were statistically significant (Table 3). By including interaction terms between steak attributes and individual characteristics we were able to account

Table 3. Random parameters logit model estimates

Variable/Description	Canadian consumers	Japanese consumers	Mexican consumers	U.S. consumers
Random Parameters (Means):				
CANADA	3.7925*	1.3449*	0.9808*	3.2135*
U.S.	1.9025*	0.3524	0.7550*	5.2469*
JAPAN	−0.6173*	2.7592*	−0.0280	0.2864
MEXICO	−1.0688*	0.0472	1.7650*	−2.0900*
NATURAL	−0.3637*	0.0228	0.0432	−1.0268*
TENDER	1.4838*	1.1606*	0.9287*	1.7684*
FOOD SAFETY 40	0.1892	0.3840*	0.2304	0.0733
FOOD SAFETY 80	1.1069*	0.9950*	0.7113*	0.6338*
Nonrandom Price Parameters for:				
Frequent Consumers, Low Income	−0.1568*	−0.0512*	−0.0959*	−0.2047*
Frequent Consumers, High Income	−0.1681*	−0.0382*	−0.0998*	−0.2535*
Infrequent Consumers, Low Income	−0.1187*	−0.0647*	−0.0512*	−0.1744*
Infrequent Consumers, High Income	−0.0788*	−0.0172*	−0.0063	−0.1733*
Nonrandom Attribute*Demographic Interaction Parameters:				
*CANADA * FEMALE*	−0.4541*	−0.8322*	−0.0897	−1.0502*
*CANADA * EDUCATION*	0.4668*	0.1325*	0.0747*	0.4488*
*CANADA * STEAK_RISK*	−0.9104*	−0.7154*	−0.2614*	−1.7766*
*U.S. * FEMALE*	−0.7517*	−1.5312*	−0.2658*	−0.7228*
*U.S. * EDUCATION*	0.4957*	0.1172	0.0328	0.3177*
*U.S. * STEAK_RISK*	−0.9612*	−1.3615*	−0.3016*	−1.6618*
*JAPAN * FEMALE*	−1.3450*	−0.5127*	−0.2062	−1.3085*
*JAPAN * EDUCATION*	0.8651*	0.1523*	0.0327	0.7100*
*JAPAN * STEAK_RISK*	−1.3662*	−0.2924*	−0.3021*	−1.6406*
*MEXICO * FEMALE*	−0.8585*	−1.0860*	−0.3120*	−1.0190*
*MEXICO * EDUCATION*	0.5820*	0.1969*	0.1373*	0.5340*
*MEXICO * STEAK_RISK*	−1.1966*	−0.7466*	−0.1004	−1.5415*
*NATURAL * FEMALE*	0.0442	−0.1948*	0.1535*	0.4705*
*NATURAL * EDUCATION*	0.0581	0.0016	−0.0087	0.0615*
*NATURAL * STEAK_RISK*	0.0538	0.0420	−0.0632*	0.3128*
*TENDER * FEMALE*	0.0588	−0.0924	−0.3679*	0.0232
*TENDER * EDUCATION*	−0.1606*	−0.0434	0.0568*	−0.2130*
*TENDER * STEAK_RISK*	−0.1580*	−0.1180*	0.0519	−0.1217*
*FOOD SAFETY 40 * FEMALE*	0.4754*	−0.0098	−0.2607*	0.5756*
*FOOD SAFETY 40 * EDUCATION*	0.0121	−0.0091	0.0999*	−0.0903*
*FOOD SAFETY 40 * STEAK_RISK*	−0.0106	−0.0971*	−0.0329	0.0270
*FOOD SAFETY 80 * FEMALE*	0.6195*	0.0341	−0.3983*	0.6464*
*FOOD SAFETY 80 * EDUCATION*	−0.0295	−0.1047*	0.1601*	−0.1991*
*FOOD SAFETY 80 * STEAK_RISK*	−0.2350*	0.1157*	−0.0674	−0.0055
Log likelihood	−12,832.40	−12,759.90	−18,323.10	−13,934.80
Pseudo R^2	0.4254	0.4316	0.1994	0.3996

Notes: One asterisk indicates statistical significance at the 0.10 level. Models were estimated using NLOGIT 4.0, with Halton draws, and 250 replications for simulated probability. Appendix presents Cholesky and correlation matrices for the model's random parameters.

for consumers with different sociodemographic status and perceptions on risk inherent in beef steak consumption, having different marginal utilities with respect to the steak attributes being analyzed. Most (ranging from 54% in the Mexican model to 88% in the U.S. model) of the interaction terms are statistically significantly different from zero (0.10 level).

Interpretation of individual coefficients must be made with caution and is generally discouraged in random utility models (Scarpa and DelGiudice 2004). Caution is particularly warranted in our models given differences in scales and the number of interaction terms between consumer characteristics and steak attributes. That is, while *ceteris paribus* interpretation of the interaction effects is feasible (e.g., Alfnes 2004), it is not advisable in our model. For instance, making statements about the impact of gender (*Female*) on the preferences for a steak attribute is based upon an unrealistic assumption of no correlation between other factors (e.g., *Education* and *Steak_Risk*).

To further evaluate preference heterogeneity in our model that allows for correlation in random steak attribute parameters we examine estimated Cholesky matrices (Appendix). The diagonal values of each Cholesky matrix represent the true level of variance for each random parameter once the cross-correlated parameters terms have been unconfounded (Hensher et al 2006). This is an important distinction in our models. For instance, all eight random parameters were estimated to have statistically significant standard deviation parameter estimates in each of the four models.[4] However, the diagonal Cholesky elements for *Food Safety 80* in our Japanese consumer model and for both *Tender* and *Food Safety 80* in our U.S. consumer model are not statistically significant (0.10 level). This implies that the statistically significant standard deviation parameters for these variables are attributable to cross-correlations with other random parameters and not heterogeneity around the mean of each random parameter (Hensher et al 2006). That is, heterogeneity of these preferences (i.e., Japanese preferences for *Food Safety 80*) manifest through relationships with other steak attributes and the interaction shift variables ($\mathbf{Z_i} \times \mathbf{x}_{jt}$) incorporated in our model.

In contrast, a majority (29/32) of the diagonal Cholesky elements are statistically significant (0.10 level). This is evidence of preference heterogeneity persisting for each steak attribute, even after incorporating consumer characteristics (via different price terms as well as interaction parameters) and allowing cross-correlations to exist across steak attribute parameters. For example, this suggests that preferences for a 40% enhancement in food safety (*Food Safety 40*) vary significantly within each population and that this heterogeneity originates from factors beyond those incorporated in our model.

Examination of the off-diagonal elements of each Cholesky matrix overwhelmingly reveals statistically significant (0.10 level) estimates (Appendix). This suggests significant cross-correlations among the random parameter estimates would have been inappropriately confused within standard deviation estimates of each random parameter without Cholesky matrix decomposition and evaluation.

Of particular interest are estimates of consumer WTP and estimates of consumer market size expected to pay various price premiums. We used simulation techniques to identify 95% confidence intervals on WTP estimates. Resulting measures are presented in Table 4 for beef guaranteed to be tender, and possessing food safety risk reduction assurances of 40% and 80%. Strong preferences for steak tenderness were revealed for consumers in all four countries with 95% confidence intervals consistently being positive.[5]

Table 4. Willingness to pay estimates and hypotheses tests

	TENDER		*FOOD SAFETY 40*		*FOOD SAFETY 80*	
	Average	95% interval	Average	95% interval	Average	95% interval
WTP of Canadian consumers for:						
Frequent Consumers, Low Income[a,c]	$4.91	($4.14, $5.66)	$2.89	($2.11, $3.62)	$3.89	($2.40, $5.30)
Frequent Consumers, High Income[a,c]	$4.57	($3.88, $5.31)	$2.70	($1.91, $3.39)	$3.60	($2.25, $4.90)
Infrequent Consumers, Low Income[a]	$6.54	($5.13, $8.11)	$3.86	($2.65, $5.10)	$5.13	($3.13, $7.17)
WTP of Japanese consumers for:						
Frequent Consumers, Low Income[a,b,c]	$13.07	($11.49, $14.70)	$1.81	(−$0.37, $3.88)	$17.99	($14.71, $21.39)
Frequent Consumers, High Income[a,b,c]	$17.51	($15.23, $19.85)	$2.53	(−$0.38, $5.41)	$24.06	($19.66, $28.60)
Infrequent Consumers, Low Income[a,b,c]	$10.33	($9.10, $11.67)	$1.48	(−$0.28, $3.16)	$14.20	($11.55, $17.00)
WTP of Mexican consumers for:						
Frequent Consumers, Low Income[a,c]	$9.51	($8.25, $10.87)	$2.34	($1.07, $3.54)	$11.81	($9.03, $14.49)
Frequent Consumers, High Income[a,c]	$9.15	($7.63, $10.59)	$2.23	($1.10, $3.34)	$11.32	($8.60, $13.97)
Infrequent Consumers, Low Income[a,c]	$18.23	($13.01, $26.00)	$4.45	($1.95, $7.50)	$22.52	($14.96, $34.55)
WTP of U.S. consumers for:						
Frequent Consumers, Low Income[a,b,c]	$4.30	($3.66, $4.94)	$1.44	($0.57, $2.23)	−$0.94	(−$2.64, $0.65)
Frequent Consumers, High Income[a,b,c]	$3.46	($2.95, $3.95)	$1.78	($0.53, $1.81)	−$0.75	(−$2.03, $0.58)
Infrequent Consumers, Low Income[a,b,c]	$5.06	($4.10, $6.08)	$1.70	($0.71,$ 2.69)	−$1.12	(−$3.11, $0.70)

Notes: Willingness to pay (WTP) estimates are presented in U.S. dollars/lb. Confidence intervals were obtained through simulation procedures (discussed on page 404).

[a,b,] and [c] denote p-values less than 0.10 associated with the null hypotheses WTP *Tender* = WTP *Food Safety 40,* WTP *Tender* = WTP *Food Safety 80, and* WTP *Food Safety 80* = 2*WTP *Food Safety 40*, respectively.

Estimates of mean WTP for tenderness assurance varied for frequent (at least weekly) beef consumers from \$3.46/lb for U.S. consumers with high income to \$17.51/lb for Japanese consumers with high income. The average WTP of \$17.51/lb may seem high relative to those of consumers in the other three countries. However, this WTP estimate applies to approximately 30% of Japanese consumers (Table 2) and grain fed beef strip loin steak price in Japan is two to three times that of similar U.S. steak prices (Clayton 2006; Sakemoto 2006). Therefore, the estimated premium for assured tender steak in Japan is similar in percentage to that of the other three countries. For less frequent (less than once per week) beef consumers of low income, mean WTP for tenderness assurance varied from \$5.06/lb for U.S. consumers to \$10.33/lb for Japanese consumers.

Table 4 also presents estimates of consumer WTP for beef steaks that have different levels of food safety enhancements. Average WTP for 40% enhancements in food safety relative to standard practices is statistically positive for Canadian, Mexican, and U.S. consumers and not different from zero for Japanese consumers. Estimates for average WTP for a 40% enhancement in food safety ranged for frequent beef consumers from \$1.81/lb for low-income Japanese consumers to \$2.89/lb for low-income Canadian consumers. For less frequent, low-income beef consumers, average estimates ranged from \$1.48/lb for Japanese consumers to \$4.45/lb for Mexican consumers.

In comparison, average WTP for 80% enhancements in food safety are statistically positive for Canadian, Japanese, and Mexican consumers and not different from zero for U.S. consumers. Average WTP for an 80% food safety enhancement by frequent beef consumers ranged from –\$0.75/lb for high-income U.S. consumers to \$24.06/lb for high-income Japanese consumers. Preferences of less frequent beef consumers for 80% enhancements in food safety range in mean WTP from –\$1.12/lb for low-income U.S. consumers to \$22.52/lb for low-income Mexican consumers.[6]

To further investigate consumer preferences regarding nonmonetary trade-offs, we compare consumer WTP for tenderness with each level of food safety enhancement assurance and also evaluate the distribution of marginal preferences for incremental adjustments in food safety risk reduction. Table 4 includes superscripts denoting results of corresponding nonparametric tests. Consumers in all four countries are willing to pay significantly more for assured tender steak than for a 40% enhancement in food safety. However, as food safety is enhanced further to 80%, consumers in Japan are statistically willing to pay more for the enhanced food safety than for tenderness assurance, U.S. consumers are willing to pay more for tenderness assurance, while Canadian and Mexican consumers are willing to pay similar amounts for the two assurances.

Table 4 also provides insight into the distribution of marginal utilities for the typical consumer in each country for food safety enhancements. In particular, we tested whether consumer WTP for an 80% enhancement in food safety was greater than twice the premium consumers would pay for a 40% enhancement. This test reveals whether WTP for food safety enhancements are convex, linear, or concave in the level of safety enhancement.

Japanese and Mexican consumers are willing to pay significantly more than twice for 80% food safety enhancement relative to what they would pay for a 40% enhancement. That is, their preferences are convex in the level of beef steak food safety enhancement. Conversely, Canadian and U.S. consumers are willing to pay significantly less than twice the premium for 80% relative to 40% food safety enhancements, suggesting a concave WTP beef steak food safety enhancement relationship. Collectively, this suggests that if constraints (e.g., state of technology, capital, etc.) are restricting such that only a 40% food safety enhancement is feasible, then investments targeting Canadian and then U.S. consumers are advisable. Conversely, if 80% enhancements in food safety are possible, investments targeting Japanese and then Mexican consumers provide the most opportunity.

Our analysis concludes by deriving estimates of the size of consumer markets likely to buy enhanced beef steak products priced with varying premiums. In particular, Table 5 presents estimates of the proportion (and accompanying 95% confidence intervals) of each consumer population WTP premiums of at least \$0.00 to \$10.00 per pound (in \$2.50 increments) for each attribute of interest. Table 5 only presents results for the largest segment (Table 2) of each country group. Based upon 95% confidence intervals, we expect at least 53% (lower tail of distribution) of each consumer segment to be willing to pay a \$2.50/lb premium for tenderness assurance. However, market size estimates fall to possibly zero for Canadian and U.S. consumer segments if the premium rises to \$5.00/lb.

Market size predictions for product labeled to have 40% less food safety risks reveal that, even if free, Japanese market share may be the smallest. Furthermore, if a premium of \$5.00/lb is required, there may not be a viable consumer market in any of the four countries. Likely market sizes for steak labeled to have 80% less food safety risks are notably stronger for Japanese and Mexican consumers. For instance, even at a \$5.00/lb premium, our model predicts at least 63% and 57% of Japanese and Mexican consumers, respectively, are willing to purchase the product. Conversely, at a \$5.00/premium Canadian and U.S. markets may be nonexistent.

POLICY IMPLICATIONS

Our analysis indicates Canadian and U.S. consumers have concave preferences for food safety enhancements and Japanese and Mexican consumers have convex preferences. These differences, especially when operating with incomplete information regarding the cost structure associated with food safety enhancement, are vital to note in policy decisions regarding beef food safety. Differences in preference structures of targeted consumer groups is a contributing factor in why the optimal provision of food safety enhancement likely varies both across and within each country. Moreover, preference differences are consistent with the range of alternative responses (i.e., border closures and trade conflicts) to beef food safety events implemented by the four countries in our study.

Estimates of "food safety enhancement" costs are difficult to obtain as one would need, at the minimum, a thorough understanding of the procedures enacted to enhance food safety vertically throughout the supply chain and how effective targeted consumers would perceive such procedural changes. Future advancements on these and related issues will further enhance the contributions of this study. An overriding point of this study is that the value of investing in additional food safety assurances rests heavily on the preference structures of heterogeneous consumers being targeted, the relative amount and effectiveness of food safety enhancement consumers perceive by the investment, and the cost structure associated with implementing the proposed food safety enhancement procedures. Accordingly, decision makers in each country need to prudently recognize these differences in deriving policies that influence food safety.

Table 5. Simulated percentage of consumers willing to buy

	Canadian frequent consumers with high income		Japanese frequent consumers with high income		Mexican frequent consumers with low income		U.S. frequent consumers with high income	
Premium ($/lb)	Mean	95% interval	Mean	95% interval	Mean	95% interval	Mean	95% interval
TENDER								
$ 0.00	86%	(64%, 100%)	98%	(84%, 100%)	85%	(62%, 100%)	88%	(65%, 100%)
$ 2.50	74%	(56%, 100%)	97%	(80%, 100%)	80%	(60%, 100%)	69%	(53%, 100%)
$ 5.00	42%	(0%, 54%)	95%	(77%, 100%)	74%	(55%, 100%)	24%	(0%, 44%)
$ 7.50	21%	(0%, 42%)	93%	(71%, 100%)	64%	(51%, 100%)	10%	(0%, 33%)
$ 10.00	11%	(0%, 34%)	90%	(66%, 100%)	45%	(5%, 100%)	5%	(0%, 24%)
FOOD SAFETY 40								
$ 0.00	77%	(57%, 100%)	63%	(48%, 100%)	67%	(52%, 100%)	66%	(52%, 100%)
$ 2.50	53%	(40%, 82%)	50%	(16%, 85%)	48%	(23%, 61%)	33%	(0%, 47%)
$ 5.00	26%	(0%, 44%)	37%	(0%, 52%)	32%	(0%, 47%)	18%	(0%, 40%)
$ 7.50	15%	(0%, 37%)	29%	(0%, 47%)	23%	(0%, 44%)	11%	(0%, 32%)
$ 10.00	9%	(0%, 30%)	23%	(0%, 43%)	17%	(0%, 40%)	6%	(0%, 27%)
FOOD SAFETY 80								
$ 0.00	72%	(54%, 100%)	89%	(66%, 100%)	85%	(63%, 100%)	42%	(0%, 54%)
$ 2.50	60%	(49%, 100%)	87%	(64%, 100%)	82%	(60%, 100%)	26%	(0%, 45%)
$ 5.00	38%	(0%, 50%)	86%	(63%, 100%)	77%	(57%, 100%)	17%	(0%, 40%)
$ 7.50	27%	(0%, 45%)	83%	(61%, 100%)	71%	(53%, 100%)	12%	(0%, 35%)
$ 10.00	20%	(0%, 41%)	81%	(60%, 100%)	61%	(45%, 100%)	8%	(0%, 31%)

Notes: Market penetration estimates were obtained through simulation procedures (discussed on page 404).

CONCLUSION

Food safety concerns have had dramatic impacts on food and livestock markets in recent years. Furthermore, food safety assurances deemed to stabilize these markets and satisfy consumer demand are costly endeavors to implement. Despite this, relatively little research has examined consumer preferences for various beef steak food safety assurances. In particular, the literature is sparse in evaluating the extent to which such preferences are heterogeneous within and across country-of-residence defined groups and in examining the distributional nature of these preferences with respect to marginal improvements in food safety.

This article addresses these issues by examining an array of beef steak preferences among consumers in Canada, Japan, Mexico, and the United States. Particular attention is devoted to evaluating how much and how many representative consumers in each country are willing to pay for marginal improvements in beef steak food safety while also examining the extent of preference heterogeneity and allowing for nonmonetary trade-offs with food safety.

Japanese and Mexican consumers have preferences that are convex in the level of beef steak food safety enhancement while U.S. and Canadian consumers have concave preferences. Optimal investment strategies hinge critically upon both consumer perception of actual food safety improvements and the distributional relationship describing the targeted consumer segment's trade-off function between WTP premiums and risk reduction levels. Moreover, the effectiveness of food safety policies in each country pivots on recognition of these differences among consumers within and across countries.

If consumers view proposed investments as only marginally improving food safety (and investment costs are similar), the beef industry may be better off investing in product eating characteristics, such as improved tenderness. Conversely, if the targeted consumer group perceives food safety investments as significantly reducing the level of food safety risk, such investments become more viable options, particularly if targeting Canadian, Japanese, or Mexican consumers. These investment inferences also have implications for public policy in these four countries. For instance, this work suggests that policies that Canadian, Japanese, or Mexican consumers view as only marginally improving food safety may not be as acceptable as equivalent policies would be to U.S. consumers.

Results showed that within a country there is significant heterogeneity in consumer preferences regarding food safety assurance attributes. Further research may help identify other factors driving this heterogeneity. Improved knowledge of factors motivating consumer behavior with respect to food safety would help policy makers identify segment-specific food safety activities that would be far more effective than a one size fits all strategy.

Improved knowledge of costs that will be incurred by the beef industry to provide additional food safety assurances could set the stage for valuable extensions of this research. An array of challenges exist in obtaining such information, which are further compounded by the fact that diverse consumer segments perceive alternative food safety risk to be of varying importance. Nonetheless, future work could seek to enhance understanding of factors influencing the supply of additional food safety assurances utilizing the results presented here pertaining to consumer demand for these attributes. Moreover, future research could examine other beef products (i.e., ground beef), other meats, and nonmeat food to determine whether our findings generalize beyond beef steak preferences.

NOTES

[1]Survey respondents were presented with a set of questions inquiring about their understanding and perceptions regarding microbiological beef food safety hazards prior to them completing the choice experiments, so they were likely conditioned with this topic on their minds as they completed the choice experiments. Moreover, future work could evaluate the sensitivity of product labeling effects to the specific measures used in providing food safety assurances.

[2]The lowest two income groups (Table 2) were identified as "low income" consumers while the lowest three beef consumption frequency groups were characterized as "frequent consumers."

[3]Models were estimated using NLOGIT 4.0 (Greene 2008), with Halton draws, and 250 replications for simulated probability. Each estimated model was robust to adjustments in starting values and the number of replications once at least 100 were being used.

[4]These standard deviations, while provided by NLOGIT, are not presented. In the context of correlated random parameters, these standard deviation parameters are not independent and Cholesky decomposition should be used to identify proper standard deviation terms (Hensher et al 2006).

[5]This comment, and those hereinafter, is made in omission of preferences by Mexican, infrequent beef consumers with high incomes. As noted previously, this group is price insensitive and hence interpretation of WTP statistics is not deemed useful.

[6]To further examine WTP distributions, a normal kernel density estimator (Hensher and Greene 2003) was used to generate density plots of each attribute in each income/consumption segment of each country. While not presented here for brevity, these plots are available upon request. In summary, the density plots for 80% food safety risk reduction WTPs are notably more dispersed in all four consumer segments than that of assured tenderness or 40% food safety risk reductions.

ACKNOWLEDGMENTS

Funding support from the National Beef Industry Development Fund managed by CanFax Research Services is greatly appreciated. We also acknowledge helpful comments from the editor and two anonymous reviewers. Any errors are the responsibility of the authors.

REFERENCES

Alfnes, F. 2004. Stated preferences for imported and hormone-treated beef: Application of a mixed logit model. *European Review of Agricultural Economics* 31: 19–37.

Alfnes, F. and K. Rickertsen. 2003. European consumers' willingness to pay for U.S. beef in experimental auction markets. *American Journal of Agricultural Economics* 85: 396–405.

Batres-Marquez, S. P., R. L. Clemens and H. H. Jensen. 2007. Mexico's changing pork industry: The forces of domestic and international market demand. *Choices* 22: 7–12.

Brewster, N. A. T. and P. D. Goldsmith. 2007. Legal systems, institutional environment, and food safety. *Agricultural Economics* 36: 23–38.

Brown, J., J. A. L. Cranfield and S. Henson. 2005. Relating consumer willingness-to-pay for food safety to risk tolerance: An experimental approach. *Canadian Journal of Agricultural Economics* 53: 249–63.

Burton, M., D. Rigby, T. Young and S. James. 2001. Consumer attitudes to genetically modified organisms in food in the U.K. *European Review of Agricultural Economics* 28: 479–98.

Clayton, P. 2006. U.S. Meat Export Federation. Personal e-mail communication, January.

Coffey, B., J. Mintert, J. Fox, T. Schroeder and L. Valentin. 2005. *The Economic Impact of BSE on the U.S. Beef Industry: Product Value Losses, Regulatory Costs, and Consumer Reactions* (Extension Bulletin MF-2678). Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Cummings, R. G. and L. O. Taylor. 1999. Unbiased value estimates for environmental goods: A cheap talk design for the contingent valuation method. *American Economic Review* 89: 649–65.

Dong, F. and H. H. Jensen. 2007. Challenges for China's agricultural exports: Compliance with sanitary and phytosanitary measures. *Choices* 22: 19–24.

Goldberg, I. and J. Roosen. 2007. Scope insensitivity in health risk reduction studies: A comparison of choice experiments and the contingent valuation method for valuing safer food. *Journal of Risk and Uncertainty* 34: 123–44.

Grannis, J. and D. Thilmany. 2002. Marketing natural pork: An empirical analysis of consumers in the mountain region. *Agribusiness: An International Journal* 18: 475–89.

Greene, W. 2008. *NLOGIT Version 4.0 Reference Guide*. Plainview, NY: Econometric Software, Inc.

Harada, S. 2006. U.S. Meat Export Federation. Personal e-mail communication, January.

Hensher, D. A. and W. H. Greene. 2003. The mixed logit model: The state of practice. *Transportation* 30: 133–76.

Hensher, D. A., J. M. Rose and W. H. Greene. 2006. *Applied Choice Analysis*. Cambridge, UK: Cambridge University Press.

Kuhfeld, W. F., R. D. Tobias and M. Garratt. 1994. Efficient experimental design with marketing research applications. *Journal of Marketing Research* 31: 545–57.

Loureiro, M. L. and W. J. Umberger. 2007. A choice experiment model for beef: What US consumer responses tell us about relative preferences for food safety, country-of-origin labeling, and traceability. *Food Policy* 32: 496–514.

Lusk, J. 2003. Effects of cheap talk on consumer willingness-to-pay for golden rice. *American Journal of Agricultural Economics* 85: 840–56.

Lusk, J., J. Roosen and J. Fox. 2003. Demand for beef from cattle administered growth hormones or fed genetically modified corn: A comparison of consumers in France, Germany, the United Kingdom, and the United States. *American Journal of Agricultural Economics* 85: 16–29.

Lusk, J. L. and T. C. Schroeder. 2004. Are choice experiments incentive compatible? A test with quality differentiated beef steaks. *American Journal of Agricultural Economics* 86: 467–82.

McCluskey, J. J., K. M. Grimsrud, H. Ouchi and T. I. Wahl. 2003. Consumer response to genetically modified food products in Japan. *Agricultural and Resource Economics Review* 32: 222–31.

McCluskey, J. J., K. M. Grimsrud, H. Ouchi and T. I. Wahl. 2005. Bovine spongiform encephalopathy in Japan: Consumers' food safety perceptions and willingness to pay for tested beef. *Australian Journal of Agricultural and Resource Economics* 49: 197–209.

Misra, S., D. Grotegut and K. Clem. 1997. Consumer attitude toward recombinant porcine somatotropin. *Agribusiness* 13: 11–20.

Misra, S. K., C. L. Huang and S. L. Ott. 1991. Consumer willingness to pay for pesticide-free fresh produce. *Western Journal of Agricultural Economics* 16: 218–27.

Muth, M. K., M. K. Wohlgenant, S. A. Karns and D. W. Anderson. 2003. Explaining plant exit in the U.S. meat and poultry industries. *Journal of Agricultural and Food Industrial Organization* 1: Article 7, 1–21.

Nahuelhual, L., M. L. Loureiro and J. Loomis. 2004. Using random parameters to account for heterogeneous preferences in contingent valuation of public open space. *Journal of Agricultural and Resource Economics* 29: 537–52.

Pearson, M. 2006. Canadian Beef Export Federation. Personal e-mail communication, January.

Poe, G. L., K. L. Giraud and J. B. Loomis. 2005. Computational methods for measuring the difference of empirical distributions. *American Journal of Agricultural Economics* 87: 353–65.

Revelt, D. and K. Train. 1998. Mixed logit with repeated choices: Households' choices of appliance efficiency level. *Review of Economics and Statistics* 80: 647–57.

Rigby, D. and M. Burton. 2005. Preference heterogeneity and GM food in the UK. *European Review of Agricultural Economics* 32: 269–88.

Roosen, J. 2003. Marketing of safe food through labeling. *Journal of Food Distribution Research* 34: 77–82.
Roosen, J., J. L. Lusk and J. A. Fox. 2003. Consumer demand for and attitudes toward alternative beef labeling strategies in France, Germany, and the UK. *Agribusiness*: *An International Journal* 19: 77–90.
Ruiz, M. 2006. Canadian Beef Export Federation. Personal e-mail communication, January.
Sakemoto, T. 2006. Canadian Beef Export Federation. Personal e-mail communication, January.
Scarpa, R. and T. DelGiudice. 2004. Market segmentation via mixed logit: Extra-virgin olive oil in urban Italy. *Journal of Agricultural and Food Industrial Organization* 2: Article 7, 1–18.
Takemichi, Y. 2006. U.S. Meat Export Federation. Personal e-mail communication, January.
Tonsor, G. T., T. C. Schroeder, J. A. Fox and A. Biere. 2005. European preferences for beef steak attributes. *Journal of Agricultural and Resource Economics* 30: 367–80.
Train, K. E. 1998. Recreation demand models with taste differences over people. *Land Economics* 74: 230–39.
Train, K. E. 2003. *Discrete Choice Methods with Simulation*. Cambridge, MA: Cambridge University Press.
Train, K. E. and T. Atherton. 1995. Rebates, loans, and customers' choice of appliance efficiency level: Combining stated- and revealed-preference data. *Energy Journal* 16: 55–69.
United States Census Bureau. 2006. International database summary demographic data. http://www.census.gov/ipc/www/idbsum.html (accessed January 17, 2007).
Zivin, J. S. G. 2006. Ensuring a safe food supply: The importance of heterogeneity. *Journal of Agricultural and Food Industrial Organization* 4: Article 2, 1–25.

Appendix. Random parameters logit model: Cholesky and correlation matrices

	CANADA	*U.S.*	*JAPAN*	*MEXICO*	*NATURAL*	*TENDER*	*FS 40*	*FS 80*
Canadian consumer model:								
CANADA	3.2214	0.7850	0.2816	0.1848	−0.1595	−0.3853	0.2173	0.3125
U.S.	2.1613	1.7053	−0.1252	−0.2000	−0.2152	−0.6375	0.1648	0.1468
JAPAN	1.0286	−2.0419	2.8482	0.9441	−0.0575	−0.0206	−0.0651	0.0825
MEXICO	0.7062	−2.1288	2.8444	1.2152	0.0333	−0.0216	−0.0374	0.0351
NATURAL	−0.1332	−0.1212	−0.1003	0.1873	0.7870	−0.3540	0.3732	0.3988
TENDER	−0.3805	−0.5341	−0.2716	−0.1458	−0.5174	0.4273	−0.0293	−0.1215
FS 40	0.2274	−0.0098*	−0.1765	0.1406	0.3953	0.5339	0.7424	0.8927
FS 80	0.6080	−0.3094	−0.2357	−0.1288	0.8789	0.4788	1.4140	0.4964
Japanese consumer model:								
CANADA	3.0257	0.9442	0.4920	0.9281	−0.3070	0.2300	0.2954	−0.2706
U.S.	4.2895	1.4958	0.4886	0.8049	−0.1830	0.3572	0.1329	−0.3393
JAPAN	1.4354	0.2132	2.5313	0.5816	−0.2020	0.2924	0.4239	0.3005
MEXICO	3.2522	−0.7600	0.5692	0.8951	−0.5887	0.3380	0.4642	−0.0819
NATURAL	−0.1655	0.1750	−0.0464*	−0.4627	0.1271	−0.6653	−0.2192	0.0180
TENDER	0.0578*	0.1070	0.0430	0.1861	−0.0881	0.0649	−0.2106	−0.2259
FS 40	0.1854	−0.2785	0.2250	0.0875*	0.4420	−0.0185*	0.1673	−0.6271
FS 80	−0.2513	−0.2364	0.4841	0.1066*	0.6339	0.0347*	−0.3077	0.0054*

(*Continued*)

Appendix. *Continued*

	CANADA	*U.S.*	*JAPAN*	*MEXICO*	*NATURAL*	*TENDER*	*FS 40*	*FS 80*
Mexican consumer model:								
CANADA	1.8335	0.5354	0.5312	0.6190	0.6987	−0.5282	−0.0980	−0.1488
U.S.	1.3938	2.1987	0.8301	0.4035	0.6661	0.1033	0.6315	0.4478
JAPAN	1.4135	1.7193	1.4583	0.2494	0.8467	−0.1125	0.4740	0.3450
MEXICO	1.3641	0.1881	−0.5410	1.6335	0.3196	−0.2506	0.2139	0.1470
NATURAL	0.1906	0.0943	0.1255	−0.0109*	0.1154	−0.1821	0.3829	0.3259
TENDER	−0.6557	0.5675	−0.2883	−0.0330*	0.3953	0.7406	0.6482	0.6607
FS 40	−0.1153	0.9532	0.0060*	0.3281	0.5013	0.1958	0.2575	0.7530
FS 80	−0.2160	0.9065	0.0544*	0.3820	0.7108	0.3803	−0.6169	0.2427
U.S. consumer model:								
CANADA	3.1106	−0.7228	−0.8534	−0.6765	0.3326	0.3485	0.2308	0.0938
U.S.	−2.0906	1.9986	0.8374	0.7798	−0.3276	−0.2616	−0.3441	−0.0672
JAPAN	−3.1945	1.1949	1.5428	0.9591	−0.2950	−0.1842	−0.2141	−0.0212
MEXICO	−3.8876	2.4184	3.4507	0.3943	−0.2045	−0.0135	−0.1315	0.0525
NATURAL	0.4266	−0.1619	0.0905	0.5828	1.0435	0.2442	0.5992	0.4615
TENDER	0.3467	−0.0140*	0.2842	0.8222	−0.3291	0.0664*	0.4614	0.2980
FS 40	0.3649	−0.4055	0.2482	0.8834	0.4374	−0.8942	0.6076	0.6727
FS 80	0.2131	0.0021*	0.3227	1.0046	0.6130	−1.7482	−0.7561	0.0121*

Notes: The lower, left-hand and diagonal elements present Cholesky matrix components; the upper, right-hand corner (shaded) elements are correlation statistics.
U.S., *FS 40,* and *FS 80* represent *United States*, *Food Safety 40,* and *Food Safety 80*, respectively.
One asterisk indicates estimates are *NOT* statistically significant at the 0.10 level.