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Perceived Risks of Conventional and Organic Produce: Pesticides, Pathogens, and Natural Toxins

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Public risk perceptions and demand for safer food are important factors shaping agricultural production practices in the United States. Despite documented food safety concerns, little attempt has been made to elicit consumers' subjective risk judgments for a range of food safety hazards or to identify factors most predictive of perceived food safety risks. In this study, over 700 conventional and organic fresh produce buyers in the Boston area were surveyed for their perceived food safety risks. Survey results showed that consumers perceived relatively high risks associated with the consumption and production of conventionally grown produce compared with other public health hazards. For example, conventional and organic food buyers estimated the median annual fatality rate due to pesticide residues on conventionally grown food to be about 50 per million and 200 per million, respectively, which is similar in magnitude to the annual mortality risk from motor vehicle accidents in the United States. Over 90% of survey respondents also perceived a reduction in pesticide residue risk associated with substituting organically grown produce for conventionally grown produce, and nearly 50% perceived a risk reduction due to natural toxins and microbial pathogens. Multiple regression analyses indicate that only a few factors are consistently predictive of higher risk perceptions, including feelings of distrust toward regulatory agencies and the safety of the food supply. A variety of factors were found to be significant predictors of specific categories of food hazards, suggesting that consumers may view food safety risks as dissimilar from one another. Based on study findings, it is recommended that future agricultural policies and risk communication efforts utilize a comparative risk approach that targets a range of food safety hazards.

KEY WORDS: Risk perception; food safety; comparative risk; organic food

1. INTRODUCTION

Survey research shows that American consumers are very concerned about food safety issues, particularly pesticide residues on food.[1–5] Pesticide-related concerns have increased significantly since the mid-1960s, and many consumers now support at least a partial ban on pesticides used on fresh produce.[6,7] Perceived food safety risks may also be a significant contributor to increased consumer demand for organically grown food. Organic foods currently comprise about 2% of the United States food market, and total organic retail sales reached $3.5 billion in 1996.[8] Many consumers believe that organically grown foods are safer and provide greater health benefits than their conventional counterparts,[5] and the percentage of consumers in the United States who bought organically grown produce in the past 6 months rose from 11% in 1990 to 26% in 1998.[9,10] Recent food safety legislation, such as the Food Quality Protection Act and the proposed National

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Organic Program, may lead to further reductions in pesticide use and an increased reliance on nonconventional farming methods in the United States.[11,12]

Despite the potential influence of public risk perceptions in shaping future agricultural policies, only a few studies have attempted to quantify consumers' subjective risk judgments with regard to food safety hazards. van Ravenswaay and Hoehn[13] found that about 42% of American consumers perceived lifetime household risks from current levels of pesticide residues on food to be 1 in 1,000 or greater, and 26% perceived lifetime pesticide residue risks of 1 in 100 or greater. In an exploratory analysis, Hammitt[14] found that organic and conventional food buyers perceived median lifetime pesticide residue risks from 1 year's consumption of conventionally grown produce to be about 850 per million and 1 per million, respectively. Eom[15] also found that consumers perceived the consumption of commercially grown produce to pose a considerable health risk and ranked the "seriousness" of such risks as 6.6 on a 10-point index scale. Research conducted by Kraus, Malmfors, and Slovic[16] suggests that most consumers believe their perceived food safety risks are justified, and Graham, Glass, Clemente, and Pasternak[17] found that both men and women are fairly confident that food pesticides pose a public health hazard. Little data are available on consumers' perceived risks of other (nonpesticide) food hazards, but Hayes, Shogren, Shin, and Kliebenstein[18] found that consumers tend to underestimate the annual probability of foodborne illness from common microbial pathogens such as *Salmonella* and *Campylobacter*.

It is also unclear what factors are the greatest contributors to higher perceived food safety risks. Huang[19] suggests that consumers who favor more restrictive regulations or do not use chemical pesticides in home gardening are more likely than others to perceive greater risks from pesticide exposures. In this study, persons who were employed, female, and married with at least one child had greater concerns about pesticide residues than did their counterparts. In addition, research suggests that women may have higher risk perceptions than men for food safety hazards. For example, on a scale from 1 ("almost no health risk") to 4 ("high health risk"), pesticides in food were rated as a 3.2 by female respondents and a 3.0 by male respondents.[20] In another study,[17] women were found to be more confident than men that pesticide residues pose a public health hazard, with average confidence scores on a 10-point scale of 6.4 and 7.4 for men and women, respectively.

The purpose of this study was to evaluate the nature and magnitude of consumers' food safety risk perceptions in greater detail. No previous known studies have elicited consumers' subjective risk judgments for a range of food safety hazards associated with both conventionally grown produce and organically grown produce. This information is important for understanding how consumers perceive food safety risks relative to one another, and to gauge public knowledge and opinions about the risks and benefits of alternative farming practices. The primary objectives of this research were to:

1. Elicit consumers' subjective risk judgments associated with the consumption and production of conventionally grown produce and organically grown produce in the United States.
2. Identify factors that are consistently predictive of perceived food safety risks or that are significant predictors of specific categories of food hazards.

2. STUDY DESIGN

To evaluate consumers' perceived food safety risks, a 14-page take-home questionnaire was developed and distributed to fresh produce shoppers in the Boston area. Sampling occurred over a 2-week period from October 5 through 18, 1998, at five major grocery stores in the Boston area that sell conventional fresh produce and five retail stores that sell a variety of organic fresh produce. To avoid potential interviewer and sampling biases, all shoppers in the fresh produce section of a store were approached and asked if they would be willing to participate in the study, and "conventional" and "organic" food stores were matched based on geographic location and average community household income. Each store was sampled on two separate occasions based on 21 randomly assigned day and time combinations. A total of 1,004 surveys were distributed nearly uniformly among the ten participating stores. Study participants received a food safety survey, a cover letter explaining the nature of the study, and a self-addressed, stamped, return envelope. Mailing addresses were also obtained from study participants and reminder cards were sent to all participants 1 week later, with a replacement survey mailed to all nonrespondents 3 weeks later.[21]

The survey contained questions about consumers' food purchasing habits, attitudes, and beliefs; sources of food safety information; perceived food safety risks; and lifestyle and demographic character-

istics. The format for most survey items was close ended (i.e., dichotomous or categorical choice questions). For example, survey respondents were asked to rate on a 5-point scale their level of agreement with 26 statements related to food safety attitudes and beliefs. A series of open-ended questions, however, was used to elicit consumers' subjective risk judgments related to conventionally grown produce and organically grown produce. Specifically, survey respondents were asked to estimate the annual fatality rate per 1 million population in the United States for each category of food hazard. Food safety hazards included risks to consumers from pesticide residues, natural toxins, and microbial pathogens on food, as well as risks to farm workers from pesticide exposure.

To ensure that respondents had the same baseline information when answering survey questions, generic definitions were provided for conventional and organic fresh produce. Conventionally grown foods were defined as those produced using modern farming practices including synthetic (i.e., manmade) pesticides and fertilizers. Organically grown foods were defined as those produced using alternative farming practices (e.g., using beneficial organisms to control pest populations, instead of synthetic pesticides and fertilizers). Respondents were informed that most food sold in the United States is conventionally grown, while about 2% of the food sold in the United States is labeled as organically grown. The food safety survey also contained definitions for pesticide residues (i.e., chemicals that remain on foods after crops have been sprayed with pesticides or have been grown in an environment containing pesticides), natural toxins (i.e., chemicals produced naturally by plants), and microbial pathogens (i.e., bacteria and other organisms that can be present in foods).

In addition, all survey respondents received a risk ladder (presented on either a linear or logarithmic scale), which indicated the annual fatality rate per 1 million people in the United States from common causes of death. The risk ladder was presented on the page opposite the risk perception questions, and a written example was provided for the number of deaths each year due to motor vehicle accidents in the United States (i.e., about 160 fatalities per 1 million population). Risk ladders have been used in survey research to present unfamiliar hazards in the context of more familiar hazards, and have been found to aid in the elicitation of respondents' subjective risk judgments.[1,14] The linear-scale version of the risk ladder was based on the one published by Hammitt,[14] while the logarithmic-scale version contained the same risk information given in the linear scale version, but presented it on a log scale. The survey instrument was pretested using cognitive interviews and multiple convenience samples to clarify the wording of survey questions and to assess the format of the survey instrument. Two pilot tests were also conducted to assess the feasibility of the sampling approach.

3. METHODS

Survey data were entered into a Microsoft Access database (Microsoft Corporation, Seattle, WA) and analyzed using STATA statistical software (State Corporation, college station, TX). All survey responses were recorded verbatim and each questionnaire was reviewed on two separate occasions to minimize coding errors. Classification of buyer type was based on whether respondents considered themselves to be an organic or a conventional fresh produce buyer. Respondents' self-identified buyer type was strongly correlated with consumers' reported purchases of organically grown food. For example, about 95% of self-identified organic food buyers reported that more than 10% of their fresh produce purchases over the last year were organic, compared with only 19% of self-identified conventional food buyers.

Eight linear regression models were developed using ordinary least squares regression to determine the factors most predictive of consumers' risk perceptions for each category of food hazard. All dependent (continuous) variables were based on consumers' estimated annual fatality rate associated with the consumption or production of conventionally grown produce or consumers' perceived change in risk associated with switching from conventionally grown produce to organically grown produce. In the latter scenario, perceived food safety risks were calculated by subtracting respondents' estimated fatality rate associated with organically grown produce from their estimated fatality rate associated with conventionally grown produce. A logarithmic transformation was performed on all dependent variables to achieve approximate normality in the distribution of highly skewed residuals, and a uniform constant of 10^{-6} was added to each outcome value to prevent the loss of zero values in the transformation process. Sensitivity analyses using alternative constants of 10^{-5} and 10^{-7} revealed only modest changes in estimated coefficients for each regression model.

Over 40 covariates or independent variables were evaluated in each regression model, including three indices related to consumers' food safety atti-

tudes and beliefs. The three index variables were based on an exploratory factor analysis of 26 attitudinal and belief statements related to a range of food safety issues and farming practices. The trade-off index was comprised of two variables related to consumers' willingness to accept greater frameworkers and environmental risks in exchange for fewer risks to consumers. The trust index was comprised of six variables related to consumers' level of trust in regulatory agencies and confidence in the safety of the food supply, while the benefits index was comprised of seven variables related to consumers' beliefs about the benefits of organically grown produce (see Table I).

The principal factors method was used for the initial extraction process and only those factors explaining at least 10% of the variance in the data and having properties of simple structure were retained for rotation.[22] Promax (oblique) procedures were used to rotate the presumed correlated factors, and variables with factor loadings having an absolute value greater than or equal to 0.40 were summarized as new index variables.[23] Factor-based scores were generated for each new index by summing the weighted values of the individual variables comprising each factor. Nonresponses on survey items were imputed using a single "hot-deck" procedure, in which Monte Carlo techniques were used to randomly sample from the distribution of available responses for each independent variable.[24,25]

The linear regression models were developed using a step-down model-building approach. The t statistic was used to remove the most insignificant variables from the full model, until all remaining covariates were significant at the 0.05 level. Diagnostic testing revealed that the residuals of the final models were normally distributed and relatively few influential observations were noted. For comparability and ease of interpretation, all final regression models were estimated using a common set of independent variables defined as the union of all variables that were individually significant in at least one of the risk perception models. Four additional logistic regression models were developed using maximum likelihood estimation to determine the factors most predictive of a "high-risk perceiver." High-risk perceivers were defined as respondents with estimated annual fatality rates of 1,000 per million population or greater for food safety hazards associated with conventionally grown produce. The same independent variables and model-building techniques used for the linear regression models were used to develop the logistic regression models.

4. RESULTS

Of the 1,004 surveys that were distributed to food store shoppers in the Boston area, 711 surveys were returned, yielding a 71% response rate for re-

Table I. Factor Loadings Based on Exploratory Factor Analysis

Statement	Factor 1	Factor 2	Factor 3
The United States food supply is safe	**−0.67**[a]	−0.07	0.01
I trust the government agencies responsible for food safety in the United States	**−0.67**[a]	−0.02	−0.06
The United States food supply is safer now than it was 50 years ago	**−0.52**[a]	−0.02	0.08
Pesticide residues on fruits and vegetables are safe if they meet government standards	**−0.51**[a]	−0.13	−0.13
The economic and social benefits of conventional farming outweigh its potential environmental and health risks	**−0.40**[a]	−0.18	−0.20
Rinsing fruits and vegetables with water will decrease the amount of pesticide residues on them	**−0.40**[a]	0.09	0.00
The government should do more to promote organic farming	0.19	**0.55**[b]	0.10
Scientific evidence shows that eating organic fruits and vegetables poses fewer health risks than eating conventional fruits and vegetables	0.13	**0.51**[b]	−0.13
Organic farmers care more about people and the environment than do conventional farmers	−0.00	**0.51**[b]	0.07
Producing conventional fruits and vegetables has greater negative impacts on the environment than producing organic fruits and vegetables	0.15	**0.50**[b]	0.11
Synthetic pesticides are more toxic than nonsynthetic pesticides	−0.14	**0.48**[b]	−0.08
Pesticide residues are more toxic than natural toxins in fruits and vegetables	0.06	**0.42**[b]	−0.03
Organic fruits and vegetables are produced using nonsynthetic pesticides and fertilizers	−0.13	**0.40**[b]	−0.05
It is acceptable to increase risks to farm workers if risks to consumers are decreased	−0.00	0.02	**−0.65**[c]
It is acceptable to increase risks to the environment if risks to consumers are decreased	−0.10	−0.04	**−0.65**[c]

[a] Variables comprising the "trust" index.
[b] Variables comprising the "benefits" index.
[c] Variables comprising the "trade-off" index.

Table II. Comparative Demographics of Survey Respondents and Boston Area

Characteristics	% Population		% Survey Respondents	
	Boston area[a]	All respondents	Organic buyer	Conventional buyer
Gender, female	53	75	78	72
Age				
18–34	48	33	29	35
35–54	28	45	52	41
>55	24	22	19	26
Race, White	73	88	89	87
Education (>18 years old)				
High school graduate or less	45	8	5	10
Some college/college graduate	42	55	56	54
Advanced degree	13	37	39	36
Household income				
<$15,000	24	6	5	6
$15,000–34,999	29	20	20	20
$35,000–74,999	34	36	33	38
>$75,000	13	39	43	37
Household size				
1–2	65	61	57	65
≥3	35	39	43	35

Source: 1990 United States Census Bureau, County Subdivision, Database: C90STF3A.
[a] Includes cities of Cambridge, Boston, Brookline, Wellesley, Somerville, Medford, Quincy, and Saugus.

spondents who agreed to participate in the study. Four of these surveys were omitted due to missing data, resulting in a total of 707 surveys for data analysis. Table II provides comparative demographic data for survey respondents (by buyer classification) and Boston-area residents. The study population contained fewer persons between the ages of 18 and 34 than are represented in the Boston area, as well as a disproportionate number of females, which reflects the greater frequency with which women do the household grocery shopping. For example, 80% of survey respondents reported that they were the primary food shopper for their household, and 79% of these shoppers were female. Survey respondents also appear to be better educated and have higher household incomes than average Boston area residents, and few sociodemographic differences were observed between the two buyer types. These findings may have been a result of the sampling strategy in which conventional food stores were matched to organic food stores, which in turn, tended to be located in more affluent neighborhoods. Approximately 39% and 61%

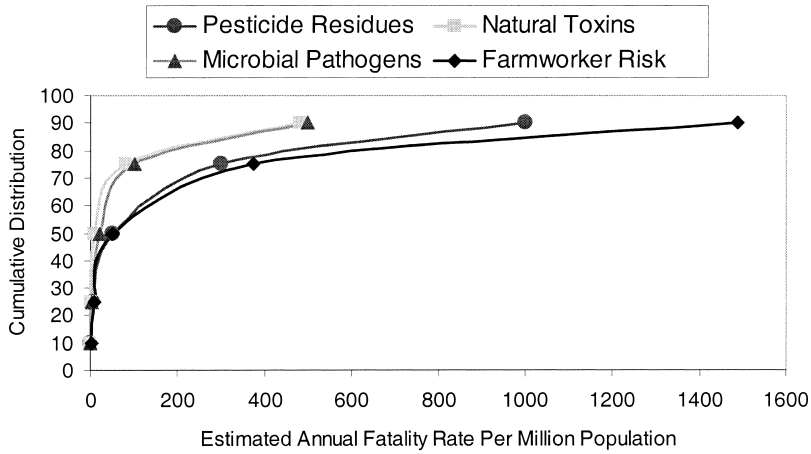

Fig. 1. Food safety risk perceptions associated with conventionally grown produce: conventional food buyers.

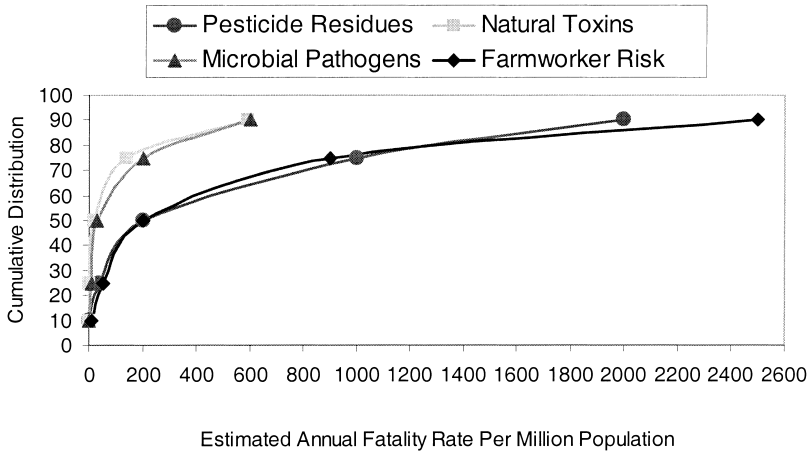

Fig. 2 Food safety risk perceptions associated with conventionally grown produce: organic food buyers.

of survey respondents were identified as organic and conventional fresh produce buyers, respectively.

4.1. Perceived Risks of Conventionally Grown Produce

Survey results indicate that both the conventional and organic fresh produce buyers perceived pesticide-related risks to pose a greater food safety hazard than either natural toxin or microbial pathogen risks (see Figs. 1 and 2). Conventional buyers estimated an annual median fatality rate due to pesticide residues on fresh produce to be about 50 per million, compared to 200 per million by organic food buyers. Although the former estimate is greater than the perceived lifetime pesticide residue risks reported by Hammitt[14] for conventional food buyers, the latter estimate is less than perceived lifetime risks reported by Hammitt for organic food buyers. Approximately 10% of conventional and organic food buyers estimated the annual fatality rate due to pesticide residues to be greater than or equal to 1,000 per million and 2,000 per million, respectively. Subjective risk judgments for these "high-risk perceivers" are comparable with estimated lifetime risks reported by van Ravenswaay and Hoehn[13] for dietary pesticide exposures.

Respondents' perceived farm worker risks were similar to their perceived pesticide residue risks at the 50th percentile, but were slightly greater at the 75th and 90th percentiles. For example, 10% of conventional and organic food buyers estimated the annual fatality rate for farm workers to be greater than 1,400 per million and 2,500 per million, respectively. These estimates are greater than the annual fatality rate for various "risky" professions in the United States, including police officers (230 per million population) and firefighters (800 per million population). Subjective risk judgments were nearly identical for natural toxin and microbial pathogen food exposures, with estimated annual median fatality rates ranging from 10 to 20 per million for conventional food buyers and 20 to 30 per million for organic food buyers.

4.2. Perceived Benefits of Organically Grown Produce

Survey results suggest that many respondents believe that organically grown produce will pose fewer risks to consumers and farm workers than conventionally grown produce (see Fig. 3). For example, over 90% of survey respondents estimated lower pesticide-related mortality risks associated with the consumption and production of organically grown produce compared with conventionally grown produce, while about 45% estimated lower natural toxin and microbial pathogen risks.

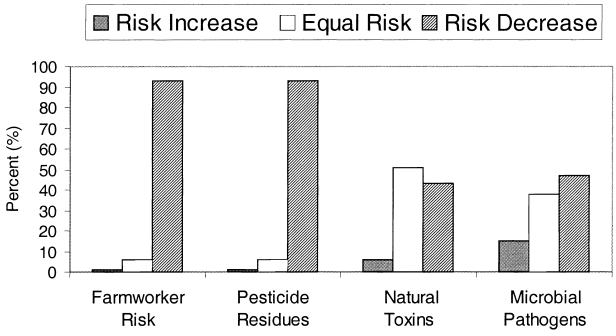

Fig. 3. Perceived change in risk associated with substituting organically grown produce for conventionally grown produce.

Table III. Average Perceived Risk Reduction from Substituting Organically Grown Produce for Conventionally Grown Produce

	Mean risk reduction per million (*SE*)[a]	
	Organic buyer	Conventional buyer
Pesticide residues	458 (44)*	207 (24)
Natural toxins	135 (24)*	68 (13)
Microbial pathogens	124 (24)*	57 (12)
Farm workers	664 (72)*	355 (43)

[a] Calculated as the difference in respondents' estimated fatality rate for conventionally grown produce and organically grown produce. Reported means and *SE*s are based on the Winsorized sample mean (i.e., observations in the upper and lower 2.5% of each distribution were replaced with the remaining highest or lowest estimated value).

* Significant difference between buyer type at the 0.01 level.

Estimated risk reductions associated with switching from conventionally grown to organically grown produce were greatest for pesticide-related hazards, particularly for farm worker risks (see Table III). For example, the reduction in average annual fatality rate was estimated to range from 207 to 355 per million by conventional food buyers and 458 to 664 per million by organic food buyers. Perceived risk reductions were lower for natural toxin and microbial pathogen risks, with estimates ranging from 57 to 68 per million and 124 to 135 per million for conventional and organic food buyers, respectively. Organic food buyers perceived significantly greater risk reductions associated with organically grown produce than did conventional food buyers for all categories of food hazard.

Not all consumers, however, perceived a risk reduction associated with substituting organically grown produce for conventionally grown produce. As indicated in Fig. 3, about 50% of survey respondents estimated identical annual fatality rates due to the consumption of natural toxins in food, while about 39% estimated identical fatality rates due to microbial pathogen exposures. In addition, about 15% of survey respondents' estimated that the consumption of organically grown produce would pose a greater microbial pathogen risk than the consumption of conventionally grown produce.

4.3. Factors Predictive of Risk Perceptions

Linear regression models had only modest explanatory power in predicting consumers' food safety risk perceptions ($R^2 < 0.20$). However, a few factors were found to be consistent predictors of respondents' subjective risk judgments (i.e., were significant in at least three out of four risk perception models at the 0.10 level). For example, lower scores on the trust index were associated with higher perceived risks from the consumption and production of conventionally grown produce (see Table IV). On the other hand, higher scores on the benefits index were associated with higher perceived risk reductions from the substitution of organically grown produce for conventionally grown produce (see Table V). Education was the only demographic factor found to be consistently predictive of perceived food safety risks, with education level being inversely related to higher risk perceptions. The belief that organic produce contains pesticide residues was also consistently predictive of lower perceived risk reductions associated with substituting organically grown produce for conventionally grown produce.

A variety of factors were found to be significant predictors of consumers' risk perceptions for specific categories of food hazards. In the risk perception models for conventionally grown produce, age was positively associated with higher perceived pesticide residue risks, while White participants were more likely than non-White participants to perceive greater risks to farm workers from pesticide exposures. Gender was a significant predictor of perceived microbial pathogen risks, with women having higher perceived risks than men; but was only associated with perceived pesticide residue risks at the 0.10 level. The reliance on newspapers or magazines as a primary source of food safety information was associated with higher perceived farm worker risks, the reliance on scientific journals was associated with higher perceived natural toxin risks, and the reliance on family or friends was associated with lower perceived microbial pathogen and farm worker risks. The belief that science and technology are causing foods to become too artificial and unnatural was associated with higher perceived pathogen risks.

In the perceived risk reduction models for organically grown produce, lower scores on the trust index were associated with higher perceived risk reductions only for pesticide-related hazards. A willingness to buy more organic produce if it cost the same amount as conventional produce was associated with higher perceived risk reductions from natural toxins, while a preference for produce grown on smaller rather than larger farms was associated with higher perceived risk reductions for farm workers. The belief that organ-

Table IV. Linear Regression Models for Perceived Food Safety Risks Associated with Conventionally Grown Produce[a]

	Pesticide residue		Natural toxin		Microbial pathogen		Farm worker risk	
Covariates	Coefficient	*t* test	Coefficient	*t* test	Coefficient	*t* test	Coefficient	*t* test
Trust index (1 = low trust; 5 = high trust)	−1.00	−5.29***	−0.57	−1.80*	−0.56	−3.11***	−0.90	−5.57***
Benefits index (1 = low benefits; 5 = high benefits)	0.92	3.34***	0.09	0.20	0.31	1.21	0.84	3.64***
Organic fruits and vegetables have pesticide residues on them[b]	−0.07	−0.58	−0.10	−0.46	0.04	0.33	0.06	0.56
Scientific and technological advances have caused foods to become too artificial and unnatural[b]	0.19	1.70*	0.30	1.61	0.31	3.00***	0.10	1.05
I would buy more organic fruits and vegetables if they cost the same price as conventional fruits and vegetables[b]	0.01	0.05	0.16	0.77	0.05	0.46	0.04	0.40
I prefer fruits and vegetables to be grown on smaller farms than on larger farms[b]	0.12	0.99	0.07	0.35	0.06	0.55	0.14	1.44
Organic fruits and vegetables are more nutritious than conventional fruits and vegetables[b]	0.01	0.11	−0.11	−0.61	0.01	0.13	−0.05	−0.55
Family or friends[c]	−0.29	−1.16	−0.41	−0.99	−0.56	−2.35**	−0.73	−3.42***
Medical doctor or health specialist[c]	0.43	1.13	−0.16	−0.24	0.51	1.38	0.25	0.77
Scientific journals[c]	0.05	0.14	1.10	1.97**	0.18	0.57	0.27	0.95
Magazine or newspaper[c]	0.23	0.77	−0.34	−0.67	−0.05	−0.18	0.52	2.00**
Gender (1 = female; 0 = male)	0.52	1.84*	0.25	0.53	0.58	2.17**	0.39	1.62
Age (years)	0.02	2.25**	0.02	1.09	0.02	1.88*	0.01	1.67
Education (1 < high school; 6 = advanced degree)	−0.33	−2.38**	−0.48	−2.07**	−0.24	−1.82*	0.00	0.01
Household income (1 ≤ $15,000; 5 ≥ $100,000)	−0.04	−0.53	−0.12	−1.07	0.03	0.43	0.00	0.05
Race (1 = White; 0 = Non-White)	0.44	1.15	−0.43	−0.68	0.18	0.50	0.70	2.21**
Self-reported political views (1 = very conservative; 5 = very liberal)	0.10	0.67	0.03	−0.13	−0.35	−2.57***	0.11	0.88
Grow own fruits and vegetables (1 = yes; 0 = otherwise)	−0.16	−0.60	−0.21	−0.47	−0.10	−0.39	−0.12	−0.52
Wear seatbelt when riding in car[d]	0.26	1.67*	0.14	−0.52	0.16	1.07	0.13	1.00
Recycle household trash[d]	−0.11	−0.93	−0.40	−2.08**	−0.27	−2.49**	−0.11	−1.10
Constant	1.70	0.91	5.39	1.79	3.47	2.03	0.87	0.56
Sample size (*N*)[e]		621		611		611		617
R^2		0.19		0.05		0.13		0.20

[a] Dependent variable is based on respondents' estimated fatality rate per 1 million population for conventionally grown produce.
[b] 1 = completely agree; 5 = completely disagree.
[c] 1 = rated within the top three most frequent sources of food safety information; 0 = otherwise.
[d] 1 = never; 5 = always.
[e] N < 707 due to missing survey data.
* Significant at 0.10 level; ** Significant at 0.05 level; *** Significant at 0.01 level.

ically grown produce is more nutritious than conventionally grown produce was associated with higher perceived risk reductions from microbial pathogens.

4.4. Factors Predictive of High-Risk Perceivers

Logistic regression models also had only modest explanatory power in predicting factors most predictive of a "high-risk perceiver" (see Table VI). For example, multiple logistic regression models correctly classified only 5% to 12% of respondents who estimated annual fatality rates greater than 1,000 per million for each category of food hazard, using a cutoff of $p > 0.50$ (where p = probability of a high-risk perceiver). The belief that it is possible to produce the same quantity of organic as conventional fresh pro-

Table V. Linear Regression Models for Perceived Risk Reductions Associated with Organically Grown Produce[a]

	Pesticide residue		Natural toxin		Microbial pathogen		Farm worker risk	
Covariates	Coefficient	*t* test	Coefficient	*t* test	Coefficient	*t* test	Coefficient	*t* test
Trust index (1 = low trust; 5 = high trust)	−1.29	−4.27***	−0.38	−0.66	−0.35	−0.60	−1.08	−3.50***
Benefits index (1 = low benefits; 5 = high benefits)	1.94	4.49***	1.36	1.71*	0.63	0.74	1.51	3.41***
Organic fruits and vegetables have pesticide residues on them[b]	−0.41	−2.02**	−0.25	0.67	−0.85	−2.17**	−0.49	−2.40**
Scientific and technological advances have caused foods to become too artificial and unnatural[b]	0.05	0.28	0.25	0.78	0.33	0.96	−0.27	−1.49
I would buy more organic fruits and vegetables if they cost the same price as conventional fruits and vegetables[b]	0.12	0.60	0.79	2.11**	0.52	1.31	0.16	0.78
I prefer fruits and vegetables to be grown on smaller farms than on larger farms[b]	0.13	0.72	0.12	0.34	0.59	1.63	0.54	2.85***
Organic fruits and vegetables are more nutritious than conventional fruits and vegetables[b]	0.21	1.22	0.40	1.22	0.88	2.54**	−0.04	−0.22
Family or friends[c]	−0.82	−2.09**	0.10	0.14	−1.11	−1.43	−1.46	−3.61***
Scientific journals[c]	−0.08	−0.16	1.87	1.94*	0.24	0.24	0.36	0.66
Magazine or newspaper[c]	0.24	0.49	−2.40	−2.64***	−1.64	−1.76*	0.29	0.57
Gender (1 = female; 0 = male)	1.00	1.69*	0.68	0.83	1.99	2.26**	0.35	0.78
Age (years)	0.00	0.14	0.05	1.84*	0.07	2.54**	−0.00	−0.10
Education (1 ≤ high school; 6 = advanced degree)	0.10	0.44	−0.91	−2.18**	−0.78	−1.82*	0.39	1.73*
Household income (1 ≤ $15,000; 5 ≥ $100,000)	−0.01	−0.11	−0.36	−1.80*	−0.30	−1.39	0.04	0.43
Race (1 = White; 0 = Non-White)	1.00	1.69*	−1.75	−1.53	−1.30	−1.11	1.57	2.60***
Self-reported political views (1 = very conservative; 5 = very liberal)	0.29	1.24	0.07	0.17	−0.59	−1.26	0.27	1.15
Grow own fruits and vegetables (1 = yes; 0 = otherwise)	−0.01	−0.01	−1.40	−1.76*	−0.43	−0.52	−0.22	−0.50
Wear seatbelt when riding in car[d]	0.19	0.79	−1.33	−2.99***	−0.84	−1.82*	−0.06	−0.23
Recycle household trash[d]	−0.23	−1.26	−0.53	−1.54	−0.26	−0.72	−0.08	−0.42
Constant	−4.21	−1.44	0.10	0.02	−1.15	−0.20	−3.36	−1.12
Sample size (N)[e]		601		567		509		604
R^2		0.21		0.15		0.15		0.17

[a] Dependent variable is based on the difference in respondents' estimated fatality rate per one million population for conventionally grown and organically grown produce.
[b] 1 = completely agree; 5 = completely disagree.
[c] 1 = rated within the top three most frequent sources of food safety information; 0 = otherwise.
[d] 1 = never; 5 = always.
[e] $N < 707$ due to missing survey data.
* Significant at 0.10 level; ** Significant at 0.05 level; *** Significant at 0.01 level.

duce in the United States was found to be consistently predictive of a high-risk perceiver. Conversely, the reliance on family or friends for food safety information was negatively associated with being a high-risk perceiver for all food hazard categories. Gender (female) and lower scores on the trust index were associated with a high-risk perceiver for pesticide-related hazards, while age was associated with a high-risk perceiver for natural toxin and microbial pathogen hazards.

Table VI. Logistic Regression Models for High-Risk Perceivers Associated with Conventionally Grown Produce[a]

	Pesticide residue		Natural toxin		Microbial pathogen		Farm worker risk	
	Coefficient	*z* test	Coefficient	*z* test	Coefficient	*z* test	Coefficient	*z* test
Trust index (1 = low trust; 5 = high trust)	−0.68	−3.50***	−0.35	−1.23	−0.07	−0.23	−0.46	−2.44**
Benefits index (1 = low benefits; 5 = high benefits)	0.55	2.25**	0.50	1.47	0.03	0.10	0.21	0.94
Trade-off index (1 = not acceptable; 5 = acceptable)	−0.22	−1.22	−0.20	−0.77	−0.52	−1.72*	−0.20	−1.11
It is possible to produce the same quantity of organic fruits and vegetables as conventional fruits and vegetables in the United States[b]	0.26	2.19**	0.49	2.61***	0.55	2.82***	0.25	2.21**
Scientific and technological advances have caused foods to become too artificial and unnatural[b]	0.02	0.21	0.07	0.41	0.61	3.28***	0.13	1.28
Family or friends[c]	−0.55	−2.19**	0.11	0.30	−0.87	−2.04**	−1.07	−4.08***
Scientific journals[c]	−0.60	−1.68*	0.38	0.84	0.78	1.65*	−0.23	−0.72
Television or radio[c]	0.13	0.52	0.56	1.47	1.21	2.88***	0.39	1.56
Gender (1 = female; 0 = male)	0.76	2.37**	0.32	0.72	0.63	1.38	0.61	2.02**
Age (years)	0.10	1.17	0.04	2.94***	0.03	2.14**	0.01	1.52
Education (1 < high school; 6 = advanced)	−0.20	−1.47	−0.26	−1.37	−0.44	−2.41**	0.00	0.04
Children (No.)	0.04	0.32	0.33	2.10**	0.12	0.66	0.11	1.01
Currently have chronic disease (1 = yes; 0 = no)	0.21	0.64	−0.02	−0.05	0.46	0.99	0.59	1.88*
Self-reported political views (1 = very conservative; 5 = very liberal)	−0.05	−0.39	−0.30	−1.50	−0.49	−2.30**	0.11	0.78
Consider self a vegetarian (1 = yes; 0 = otherwise)	0.29	0.91	0.98	2.26**	0.73	1.61	0.44	1.37
Risk ladder version (1 = log scale; 0 = linear scale)	0.27	1.18	0.68	1.87*	0.42	1.17	0.04	0.17
Constant	−2.27	1.18	−6.19	−2.64	−5.19	−2.17	−3.58	−2.26
Sample size (*N*)[d]		621		611		611		617
% Correctly classified as "high-risk perceiver"		11		5		12		6

[a] Dependent variable is based on respondents who estimated an annual fatality rate equal to or greater than 1,000 per million population for conventionally grown produce.
[b] 1 = completely agree; 5 = completely disagree.
[c] 1 = rated within the top three most frequent sources of food safety information; 0 = otherwise.
[d] $N < 707$ due to missing survey data.
* Significant at 0.10 level; ** Significant at 0.05 level; *** Significant at 0.01 level.

5. DISCUSSION

Public concern over food safety issues, particularly pesticide residues on food, has been well documented in consumer research studies. However, the magnitude of consumers' risk perceptions, as well as the factors most predictive of perceived food safety risks, remain largely unknown. The current study provides data on consumers' subjective risk judgments for a range of food safety hazards associated with conventionally grown produce and organically grown produce. Specifically, data are provided on consumers' perceived annual fatality rate per million population in the United States due to exposure to pesticides, natural toxins, and microbial pathogens.

Study results reveal several important findings. First, consumers perceive relatively high risks associated with the consumption and production of conventionally grown produce compared with other public health hazards, particularly for pesticide-related risks. Second, many consumers perceive a significant reduction in pesticide-related risks associated with

substituting organically grown produce for conventionally grown produce. These findings suggest that increased consumer demand for organically grown foods may be driven in large part by the perception that organic foods provide significant health benefits compared with conventional foods. Although preliminary testing data indicate that organically labeled produce contain fewer types of synthetic pesticide residues than their conventional counterparts, the degree of risk reduction (if any) achieved by switching from conventional to organic foods has not been determined.[26,27] Organic farming methods also rely on a variety of nonsynthetic pesticides, such as pyrethrum and rotenone, which have not been tested in traditional pesticide residue screening analyses.

Third, linear regression modeling indicates that several factors are consistently predictive of higher perceived food safety risks. In particular, consumers' level of trust in government agencies and confidence in the safety of the food supply is a significant predictor of food safety risk perceptions. This finding suggests that risk communication efforts designed to educate consumers about food safety hazards may need to focus on broader issues related to the credibility of regulatory agencies and information sources. Consumer research indicates that government agencies lack credibility among consumers, and consumer confidence in the adequacy of government regulations on pesticide use has decreased dramatically since the mid-1960s.[4,6] The psychological literature also suggests that risk messages focused only on scientific evaluations may not be accepted if the information source is viewed as untrustworthy.[28,29]

Fourth, many factors were found to be significant predictors of specific categories of food hazards, suggesting that consumers may view food safety risks as dissimilar from one another. In particular, consumers appear to distinguish pesticide-related risks from natural toxin and microbial pathogen risks, but do not necessarily distinguish between these latter hazards. It is unclear whether consumers really view the risks of natural toxins and microbial pathogens as similar to one another or whether this finding is a result of respondents' limited familiarity with these hazards. Although many consumers believe that substituting organically grown produce for conventionally grown produce will reduce risks from natural toxins and microbial pathogens, scientific data are not available to support these perceptions. In contrast, there is some concern in the scientific community that organic foods may increase natural toxin exposures because "stressed" or damaged plants tend to produce more of their own natural chemicals to protect against pest attacks,[30] or may increase microbial pathogen exposures due to the use of manure fertilizers on organic farms.[31]

The results presented here provide useful information on the nature and magnitude of consumers' subjective risk judgments, but should be interpreted with some caution. The sample contains a disproportionate number of females and highly educated persons with high household incomes due to the nature of the sampling design. Also, consumers in the Boston area may also not be representative of consumers' risk perceptions in other regions. Interviewer observations recorded at the time surveys were distributed indicated that food shoppers who refused to participate in the study tended to be male, elderly, non-White, and non-English speaking. Future research efforts should, therefore, pay particular attention to certain population groups that may be underrepresented in survey research. The difficult nature of eliciting subjective risk judgments and the relative high perceived food safety risks reported here, also raise questions regarding the reliability and meaningfulness of consumers' responses. However, despite potential cognitive challenges, the item response rate for the risk perception questions in this study was approximately 85%. Estimated fatality rates also tended to fall within the range of values presented in the risk ladder, suggesting that consumers may have thought about each food hazard category within the context of other public health hazards before formulating a response. Previous studies indicate that although consumers' perceived food safety risks seem very high, they may be within the range of uncertainty for pesticide-related risks or comparable with worst-case estimates reported by regulatory agencies.[13,14]

Based on study findings, it is recommended that future agricultural policies and risk communication efforts utilize a comparative risk approach that targets a range of food safety hazards. Visual aids, such as risk ladders, may help consumers put food safety risks in the context of other public health hazards, but more empirical research is needed to evaluate the effectiveness and potential framing effects of such visual aids. In the current study, respondents did not appear to anchor on any particular hazard presented in the risk ladder and average annual fatality rate estimates did not differ significantly between the linear- and logarithmic-scaled versions of the risk ladder. More research is also required to better understand the key determinants of perceived food safety risks and how consumers reach their risk judgments for

pesticide exposures versus other categories of food hazards (i.e., "mental models"). For example, previous research suggests that pesticide risks are perceived to be involuntary and uncontrollable, while natural chemicals are judged to be less risky than manmade chemicals.[16,32] Data on how consumers perceive a variety of other food safety hazards, such as genetically modified foods, irradiated foods, and hormones and antibiotics used in food production, would also be informative. Finally, information on the actual risks and benefits of organically grown produce compared with conventionally grown produce, as well as consumers' valuation of food safety risk reductions, are necessary to evaluate the impacts of policies designed to improve food safety.

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