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An Empirical Analysis of United States Consumers' Concerns About Eight Food Production and Processing Technologies

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For a representative sample of US consumers, we analyze ratings of concern toward eight food production and processing technologies: antibiotics, pesticides, artificial growth hormones, genetic modification (GM), irradiation, artificial colors/flavors, pasteurization, and preservatives. Concern is highest for pesticides and hormones, followed by concern about antibiotics, genetic modification, and irradiation. We document standard relationships between many demographic, economic, and attitude variables and the average concern level. Our main contribution is identifying three clusters of technologies that engender similar patterns of concern ratings among respondents and estimating models that correlate key personal and household characteristics to these underlying technology concern factors. We find that several individual characteristics that yield little explanatory power for average ratings have discriminatory power for explaining concern across different technology clusters.

Key words: consumers, factor analysis, food, risk perception, technology

Introduction

Modern science is capable of generating incredible advances in food production and processing technologies that can produce more food, reduce costs, and enhance attributes in ways not imagined only decades ago. However, due to the intimate and ubiquitous role that food plays in our life, the impacts of food production and processing on the environment, and the social and physical distance between consumers and the food production process, consumers scrutinize not only the cost and attributes of food but, increasingly, the technology and methods used in food production and processing.

The adoption of emerging food technologies or the rejection of existing technologies hinges on the outcome of this increasingly intense scrutiny. In this article, we analyze the concerns that US consumers express toward several prominent food production and processing technologies using data from a large representative survey. First, consumer concerns across eight technologies—antibiotics, pesticides, artificial growth hormones, genetic modification (GM), irradiation, artificial colors and flavors, pasteurization, and preservatives—are ranked. Second, correlations across the level of concern expressed for each technology are presented. Third, we use factor analysis to identify common unobserved factors driving common concerns across the eight technologies. Finally, the economic, demographic, and attitudinal variables that explain both the average level of concern with the eight technologies of interest and the unobserved concern factors are investigated using regression techniques.

Ranking the level of concern for each technology is of interest, because the data are gathered from a representative sample of US consumers. Hence, ranking provides a view of which technologies were of greatest concern at the time the data were collected (summer 2002). The correlation across concern expressed for different technologies is of interest, because it allows for speculation about the common elements of technologies that can cause consumer reticence. The factor analysis formalizes this speculation by statistically identifying common unobserved factors that explain the correlation of ratings across the eight technologies. Finally, exploring the demographic, economic, and attitudinal correlates of expressed concern (in terms of both the average concern rating and the concern factors) has several possible benefits. First, such analysis using US data can be compared to similar analyses of data from other countries to look for commonalities and differences. For example, are differences in expressed concern between the United States and European consumers due to a simple difference in demographics, attitudes, or other characteristics? Second, how might US consumer acceptance of technologies change over time as demographics shift? Alternatively, do niches of US consumers currently exist that are more accepting of various technologies?

The remainder of the paper is organized as follows. First, previous work analyzing consumer concern with

food production and processing technologies is reviewed. Next, the data and the statistical methods used to analyze the data are described, followed by the results and accompanying discussion. The final section provides conclusions and outlines avenues for future research.

Previous Research on Consumer Concern with Food Technologies

Many researchers have studied consumer attitudes, perceptions, and acceptance of various food production and processing technologies, with the bulk of recent efforts focused on genetic modification, irradiation, artificial hormones, and pesticides. Many studies document consumer demand for products differentiated with respect to a single technology (e.g., Baker, 1999 [pesticides]; Hayes, Fox, & Shogren, 2002 [irradiation]; Teisl, Roe, Vayda, & Ross, 2003 [GM foods]) or several technologies (Lusk, Roosen, & Fox, 2003 [hormones and genetic modification]; Sylvander & Le Floc'h-Wadel, 2000 [organic]). Several organizations have also conducted opinion polls to document public awareness and attitude towards various technologies (Abt Associates, 1997 [several technologies]; Center for Science in the Public Interest, 2001 [genetic modification]; Fox, Bruhn, & Sapp, 2001 [several technologies]; Gallup, 1993 [several technologies]; International Food Information Council, 2003 [genetic modification]). Closer in spirit to the current article are studies decomposing consumer attitudes and perceptions of one or more technologies (e.g., Dosman, Adamowicz, & Hrudey, 2001 [additives and pesticides]; Fife-Schaw & Rowe, 1996 [several technologies]; Frewer, Howard, & Shepherd, 1995 [genetic engineering]; Govindasamy & Italia, 1998 [pesticides]; Grobe, Douthitt, & Zepeda, 1999 [bovine growth hormone]; Hoban, 1998 [genetic modification]; Misra, Fletcher, & Huang, 1995 [irradiation]; Verdurme & Viaene, 2003 [genetic modification]).

Several common findings emerge across these articles. In most, women perceived greater risks than men (Dosman et al., 2001; Fox et al., 2001; Grobe et al., 1999; Misra et al., 1995). Misra et al. (1995) found that females treated food irradiation as more serious problem even though women had lower stated awareness of irradiation. Dosman et al. (2001) found that gender was the only variable that was robust across risk perception models estimated for food additives, food bacteria, and pesticides.

In some research, household income is associated with risk perception (Dosman et al., 2001; Grobe et al., 1999; Misra et al., 1995). Lower income respondents generally perceived more risk than higher income respondents. Misra et al. (1995) found that education level significantly affects risk perception for irradiation and suggested that female respondents with less than a college education and low income treat irradiation as a more serious problem. Dosman et al. (2001) also suggested that highly educated respondents usually perceive less risk in the sphere of food safety.

Fox et al. (2001) included the presence of children in their study; Grobe et al. (1999) included the presence of children younger and older than six years of age; and Dosman et al. (2001) included the number of children. Both the presence of children and the number of children had significant effects. Households with children had more negative views of irradiation than households without children (Fox et al., 2001); as households had more children, they perceived more risk related with food safety (Dosman et al., 2001). Grobe et al. (1999) found that only households with younger children had significantly higher perceived risks of bovine growth hormone.

Table 1. Socioeconomic characteristics of respondents.

	Survey	US census
Percent male	46	48
Average age	53	47
Average years of education	14	13
Percent white	89	75
Average household income	$60,900	$57,000

Data and Empirical Methods

During the summer of 2002, a mail survey was administered to a nationally representative sample of 6,172 US residents, which included an additional oversample of 710 individuals from one researcher's home state. In total 2,387 individuals responded (38.7%). For the questions analyzed in this article, 1,656 respondents provided complete information, yielding an effective response rate of 26.8%.

Due to the oversampling of residents from one researcher's home state, the entire sample was weighted by US census measures of state level population. Except for race, survey respondents have characteristics similar to those of the US adult population (Table 1). The differences in race may reflect a bias in our sampling frame or may reflect differences in the phrasing of the race question between our survey and the US census. Weighting the sample by both state and race category was considered but rejected, as many weighting cells (e.g., non-

Table 2. Explanatory variables.

Variable	Description
Conc US	Concern about the way foods are produced and processed in the United States on a five-point scale with 1 implying *not at all concerned*, 3 implying *somewhat concerned* and 5 implying *very concerned*.
Conc Otr	Concern about the way foods are produced and processed countries other than the United States on a five-point scale with 1 implying *not at all concerned*, 3 implying *somewhat concerned* and 5 implying *very concerned*.
Purch Org	The frequency of purchase of organic food on a five-point scale with 1 implying *never* and 5 implying *always*.
Nutr Label	The frequency of reading of food nutrition labels on a five-point scale with 1 implying *never* and 5 implying *always*.
Female	Qualitative variable. 1 if female, 0 if male.
White	Qualitative variable. 1 if Caucasian, 0 otherwise.
AGE	Qualitative variables. AGE <30: 1 if age ≤ 30 years. AGE 30–65 1 if 30 < age ≤ 65 years, 0 otherwise. AGE >65: 1 if age > 65 years, 0 otherwise.
EDU	Qualitative variables. Edu1: 1 if 0–11 years, 0 otherwise. Edu2: 1 if 12 years (high school graduate or equivalent), 0 otherwise. Edu3: 1 if 1–3 years college (some college), 0 otherwise. Edu4: 1 if college graduate, 0 otherwise. Edu5: 1 if more than an undergraduate degree, 0 otherwise.
Child 5	Number of children ≤ 5 years old.
Child 10	Number of children 6–10 years old.
Child 18	Number of children 11–18 years old.
Grow Veg	1 if household grows own vegetables, 0 otherwise.
Farm Mkt	1 if respondent shops at a farmers' market or health food store regularly, 0 otherwise.
Food Coop	1 if respondent is a member of a food cooperative, 0 otherwise.
No Diet	1 if respondent follows no dietary restrictions,[a] 0 otherwise.
Food Job	1 if respondents works in certain food system jobs,[b] 0 otherwise.
Income	Qualitative variable. Inc Low: 1 if income is < $5,000 per year, 0 otherwise. Inc Med: 1 if income is $5,000–95,000, 0 otherwise. Inc High: 1 if income is > $95,000, 0 otherwise.

[a] *Dietary restrictions include diabetic diet, low-fat diet, high-fiber diet, food allergies/sensitivities, vegetarian diet, low-sodium diet, kosher sodium diet, and others.*

[b] *The fields include large-scale conventional farming, small-scale conventional farming, large-scale organic farming, small-scale organic farming, dairy farming or livestock farm, food processing, grocery store, cook, caterer or restaurant owner, or other agricultural or food processing work.*

white respondents from North Dakota) were not represented in the sample.

The key data recorded in the survey are raw ratings provided in response to the following prompt: "Listed on this page are different items related to the way foods are produced or processed. Review the list and rate how concerned you are with each item." For each technology, respondents circled a number on a scale that ranged from one (*not at all concerned*) to three (*somewhat concerned*) to five (*very concerned*).

The list included the following terms: antibiotics, pesticides, artificial growth hormones, genetically modified ingredients, irradiation, artificial colors or flavors, pasteurization, and preservatives. The order of presentation of these items within the survey was uniform across all respondents. Hence, we are unable to test for the presence of order effects, that is, to test for the possibility that the order of presentation of the items influences the rating each item receives. Thus, we cannot rule out that the results are an artifact of item ordering.

Only four questions and a cover letter preceded this set of questions, and none of these materials mentioned or described any of the eight technologies nor attempted to gauge individual awareness of any technology.

Hence, responses should be considered "top-of-the-mind" reactions that rely upon the respondent's knowledge at the time of the survey and not upon reaction to any information provided in the survey.

Standard income and demographic variables (age, education, race, gender, occupation) were also collected, as were several attitudinal variables that might correlate to concern about food technologies. These include the respondent's general concern with the food production and processing practices in the United States and foreign countries (not specifically related to technology); the respondent's tendency to read nutrition labels; whether the respondent follows any type of special diet (e.g., low salt, low fat); whether the respondent regularly purchases organic foods; whether the respondent purchases food at farmers' markets or health food stores; and whether the respondent frequents food cooperatives or grows his/her own produce. Each response may be correlated with underlying concerns about specific food production and processing technologies and may help clarify our portrait of these concerns. (See Table 2 for a list of explanatory variables and descriptions.)

Beyond summarizing how respondents rated their concern for each of the eight technologies of interest (antibiotics, pesticides, artificial growth hormones, genetic modification, irradiation, artificial colors and flavors, pasteurization, and preservatives) and assessing correlation of concerns across these technologies, we conducted a factor analysis of the sequence of responses to the eight technology concern ratings. Factor analysis is a statistical technique that is commonly used to identify unobservable factors underlying respondents' answers to a series of questions. In essence, factor analysis finds underlying commonalities, or *factors*, in responses. For each respondent i and each identified concern factor k, a factor score $y_{i,k}$ is estimated using principal factor analysis. These factor scores are then modeled as a function of income, demographic, and other household and personal characteristics. The resulting model for respondent i's technology concern factor k is $y_{i,k} = X_i\beta_k + u_{i,k}$, where X_i is a vector of explanatory variables for respondent i, β_k is a conformable vector of parameters for technology factor k to be estimated, and $u_{i,k}$ is an unobserved component driving technology factor score k for respondent i. The factor scores are continuous variables, and a common block of explanatory variables is used for each factor score; hence, ordinary least squares regression provides consistent and efficient estimates of the model parameters in the equation.

A model was also estimated to find correlations between the average raw concern rating across all eight technologies and the common block of explanatory variables. To accommodate some censored observations (e.g., a respondent rating all technologies at the highest level of concern), a double-hurdle tobit model was employed.

Table 3. Average raw ratings of concerns about food technologies.

Pesticides	4.17 a
Artificial growth hormones	4.00 b
Antibiotics	3.77 c
GM ingredients	3.73 c
Irradiation	3.58 d
Preservatives	3.21 e
Artificial colors/flavors	3.07 f
Pasteurization	2.77 g

Note. Raw ratings are as follows: 1 = not at all concerned, 3 = somewhat concerned, and 5 = very concerned. Results sharing the same letter are not significantly different. These results were first reported in a companion paper previously published by several of the authors (Teisl, Garner, Roe, & Vayda, 2003).

Results

Rating the Level of Concern for All Eight Technologies

The average ratings of the eight technologies (listed in Table 3) reveal the average state of concern for this sample of US consumers during the summer of 2002. The ratings suggest that pesticides and artificial growth hormones generated the most concern from US consumers, while technologies such as pasteurization, artificial colors and flavors, and preservatives generated significantly less concern. Antibiotics, genetic modification, and irradiation raised intermediate levels of concern.

The two technologies of greatest concern share several commonalities. First, both artificial hormones and pesticides can reside in or on food eaten by consumers, although the exact amount that enters the body and the exact health impacts of this consumption remain uncertain. The use of both artificial hormones and pesticides can also have spillovers for the environment, with popular press accounts of the appearance of both pesticides and artificial hormones in water supplies and the ecosystem. The higher average rating for pesticides may derive from its broader reach—nearly all nonorganic fruits, vegetables, and grains use pesticides—whereas artificial growth hormones are only issues for a subset of animal products.

The technologies of intermediate concern—antibiotics, genetic modification, and irradiation—have fewer

Table 4. Correlation coefficients between ratings (*n* = 1,504).

	Antibiotics	Pesticides	Hormones	Pasteuriza-tion	Artificial color/flavor	GM	Irradiation	Preserva-tives
Antibiotics	1.000							
Pesticides	0.071 (0.006)	1.000						
Hormones	0.021 (0.426)	0.080 (0.002)	1.000					
Pasteurization	-0.250 (0.000)	-0.263 (0.000)	-0.514 (0.000)	1.000				
Artificial color/flavor	-0.152 (0.000)	-0.250 (0.000)	-0.235 (0.000)	-0.070 (0.006)	1.000			
GM	-0.123 (0.000)	-0.130 (0.000)	0.358 (0.000)	-0.398 (0.000)	-0.258 (0.000)	1.000		
Irradiation	-0.265 (0.000)	-0.094 (0.000)	-0.052 (0.046)	-0.191 (0.000)	-0.217 (0.000)	0.147 (0.000)	1.000	
Preservatives	-0.222 (0.000)	-0.188 (0.000)	-0.451 (0.000)	0.352 (0.000)	0.112 (0.000)	-0.434 (0.000)	-0.314 (0.000)	1.000

Note. p-values are in parentheses.

ways of affecting the consumer or have attributes that may be positive. For example, unlike pesticides and artificial hormones, the concern for antibiotics arises not from the possibility of direct consumption by consumers, but because some worry that widespread antibiotic use in animal agriculture will speed the general rate of antibiotic resistance. Consumers may also view antibiotic use to have some benefits, such as improving the health of animals and hence the quality of animal products consumed.

Consumer concern about genetically modified ingredients tends to lie with unknown long-term concerns about human and environmental health, but consumers may also be aware of GM technologies that reduce environmental damage or increase food's healthfulness. Likewise, irradiation is seen by some as an efficient means for preserving food safety, while others worry about its effect on food nutrient value and the environment.

The technologies of least concern are all well established in the minds of most consumers. Preservatives and artificial colors/flavors are often revealed in ingredient lists and have not stirred much media attention since the 1970s, whereas pasteurization is a well-accepted technology associated with improving the safety of milk and other beverages.

Correlation of Relative Concerns Across Technologies

Nearly all correlation coefficients for the eight normalized ratings are significantly different from zero at the .01 level of significance (Table 4). Large positive correlations exist among several clusters. The first cluster involves the technologies of lesser concern: Relative concern for preservatives is positively correlated with relative concern for pasteurization and artificial colors and flavors. Two of the technologies with moderate concern ratings are positively correlated (genetically modification and irradiation) as are the top two technologies of concern (pesticides and hormones).

Relative concern for antibiotics is significantly correlated to relative concern for pesticides (though the absolute magnitude of the coefficient is rather small), but antibiotic concern is uncorrelated with concern for artificial hormones. Also, the relative ratings for antibiotics and genetic modification are negatively correlated despite the statistical similarity of absolute concern for both technologies. That is, the average rating of concern is almost identical, but individuals rarely rated the two technologies on the same side of average. This suggests that different forces may drive the concern behind each technology—a topic which will be explored in greater detail below.

Factor Analysis

The factor analysis reveals three significant underlying factors influencing responses to the eight technology

Table 5. Models of average concern and three technology concern factor scores (n = 1,504).

	Factors			
Explanatory variable	**HGI**	**OLDTECH**	**ANTIPEST**	**Average rating**
Intercept	-2.394*** (-17.98)	0.517*** (2.99)	0.097 (0.56)	1.214*** (9.94)
Conc US	0.433*** (19.60)	0.016 (0.56)	0.105*** (3.66)	0.417*** (20.63)
Conc Otr	0.074*** (3.88)	-0.041* (-1.66)	-0.066*** (-2.67)	0.916*** (5.19)
Purch Org	0.129*** (5.53)	-0.035 (-1.17)	-0.033 (-1.10)	0.779*** (3.63)
Nutr Label	0.038* (1.69)	-0.073** (-2.50)	0.025 (0.85)	0.656*** (3.21)
Female	0.247*** (6.01)	0.006 (0.12)	-0.100* (-1.88)	0.245*** (6.48)
Age < 30	-0.180** (-2.47)	-0.126 (-1.34)	-0.161* (-1.70)	-0.151** (-2.23)
Age > 65	-0.162*** (-3.00)	0.121* (1.74)	0.147** (2.10)	-0.899** (-1.84)
Child 5	0.069 (1.60)	-0.065 (-1.16)	-0.059 (-1.06)	0.279 (0.69)
Child 10	-0.107** (-2.40)	-0.111* (-1.91)	-0.025 (-0.43)	-0.858** (-2.07)
Child 18	-0.059** (-1.96)	-0.031 (-0.79)	-0.050 (-1.29)	-0.508* (-1.81)
Grow Veg	0.073* (1.66)	-0.021 (-0.38)	0.033 (0.59)	0.333 (0.83)
Food Coop	-0.158 (-0.89)	-0.173 (-0.75)	-0.318 (-1.39)	0.109 (0.73)
Farm Mkt	0.050 (1.04)	0.025 (0.40)	0.103* (1.65)	0.726* (1.65)
No Diet	-0.023 (-0.52)	-0.107* (-1.86)	-0.071 (-1.24)	-0.406 (-1.00)
Edu1	0.131 (1.20)	0.380*** (2.69)	-0.041 (-0.29)	0.114 (1.15)
Edu2	0.320*** (4.72)	0.111 (1.27)	-0.215** (-2.44)	0.319*** (5.10)
Edu3	0.181*** (2.87)	0.166** (2.03)	-0.066 (-0.81)	0.186*** (3.18)
Edu4	0.098 (1.55)	-0.007 (-0.08)	-0.032 (-0.39)	0.558 (0.94)
White	-0.182*** (-2.85)	-0.100 (-1.20)	-0.116 (-1.40)	-0.197*** (-3.42)
Food Job	-0.102 (-1.29)	0.036 (0.35)	-0.022 (-0.21)	-0.236*** (-3.19)
Inc Low	0.317*** (2.82)	0.058 (0.40)	0.050 (0.34)	0.324*** (3.32)
Inc High	-0.199*** (-3.58)	0.031 (0.43)	0.005 (0.07)	-0.168*** (-3.26)
R^2		System-weighted: 0.22		Consistent: 0.42

Note. t-values are in parentheses. The consistent R^2 value associated with the average rating model is obtained after dropping 152 observations with values of 1 or 5 for an average rating and estimating the model using OLS.
**p < .1. **p < .05. ***p < .01.*

concern questions (Table 6). One factor features heavy loadings by individuals' responses to concern about artificial growth hormones, genetically modified ingredients and irradiation (hereafter, the *HGI* factor). Factor two relates to the concern surrounding several older technologies, including pasteurization, artificial colors/flavors, and preservatives (hereafter, the *OLDTECH* factor); concerns about antibiotics and pesticides load heavily on a third factor (hereafter, the *ANTIPEST* factor). The analysis formalizes and refines the intuition gained by studying the correlation coefficients among the raw concern ratings. Three distinct technology clusters are identified.

Average Concern Ratings Model

The model of average concern across all technologies reveals several strong predictors (Table 5, column 5). The strongest positive influence on average concern is

Table 6. Factor analysis of concern ratings for eight technologies.

	Standardized rotated factor loadings		
Technology	**Factor 1: HGI**	**Factor 2: OLDTECH**	**Factor 3: ANTIPEST**
Antibiotics	-0.32	-0.09	0.86
Pesticides	-0.02	-0.05	0.46
Artificial growth hormones	0.36	-0.20	0.12
Genetic modification	0.50	-0.09	-0.17
Artificial colors & flavors	0.05	0.31	-0.10
Irradiation	0.50	0.06	-0.35
Pasteurization	-0.13	0.52	-0.12
Preservatives	-0.16	0.46	0.03
Variance explained by factor	2.27	2.13	1.53

the respondent's general stated level of concern about how food is produced in other countries (this question does not mention technology). Previous focus group work suggests that people with concerns about foreign produce often focus on the general level of sanitation of imported produce and animal products or the presence of chemical residues on imported produce (where respondents are often worried that other countries may allow application of chemicals currently banned in the United States; see Roe et al., 2000, for a more detailed discussion). Hence, if the latter element dominates the respondent's thinking, the positive relationship is quite logical: These individuals are generally concerned with technologies such as pesticides that could be consumed with foreign food. If the former element is the true trigger of concern about foreign food production, the link to concern about food technologies is less obvious and may instead be linked to individuals who have reflected upon the interconnectedness of food systems, even across national borders.

A respondent that purchases organic food, reads nutrition labels, and shops at farmers' markets or health food stores also provides higher average ratings. Organic purchasing guarantees that many of the eight technologies are not used; organic and other "natural" foods are often widely available in health food stores; and label readers are motivated to learn about the content of processed foods.

Controlling for the above lifestyle and concern characteristics, we find that several economic and demographic variables are significantly associated with average rating. Females and lower income respondents provided higher average ratings and, compared to those with the highest levels of formal education, individuals with a high school degree and some college education provided significantly higher average ratings. Higher concern by female respondents is consistent with previous findings and may suggest greater female responsibility in food preparation, which persists despite significant increases in female workforce participation over the past decades. The higher ratings from those with lower levels of formal education are also consistent with previous findings (Dosman et al., 2001).

Lower average ratings are associated with the oldest (> 65 years) and youngest (< 30 years) respondents. This is consistent with Teisl, Levy, & Derby (1999), who found that health-related awareness is lower when young, increases with age through middle age, and then decreases with further increases in age. Lower average ratings are also associated with households with older children (compared to no children), Caucasian respondents, higher income respondents, and respondents employed in food system occupations. Our finding that respondents with older children have lower levels of concern is inconsistent with previous findings in the literature and may warrant future research to refine the correlation between concern and household structure.

Factor Models

Columns 2–4 in Table 5 provide the estimated parameters for the models that correlate individual factor scores to personal and household characteristics. A positive coefficient means that the characteristic is positively correlated with the particular underlying factor mentioned in that column; that is, the characteristic is positively correlated with the unobserved factor, which is positively correlated with higher levels of concern for that particular cluster of technologies.

These factor models refine the insight provided by the average rating model listed in column 5 of Table 5 by decomposing the characteristics that correlate to the underlying factors of technology concern. Some characteristics have the same qualitative influence on average rating and on all factor scores (e.g., concern with how food is produced in the United States and the youngest age category). However, some characteristics that are not significantly correlated to the overall level of concern are significantly correlated to individual factors (e.g., growing a vegetable garden or adhering to a dietary restriction like a low-sodium diet). Other characteristics that are significant correlates of the overall concern rating may have a positive significant correlation to one factor while simultaneously having a negative significant correlation to another factor (e.g., gender and the oldest age category).

In general, factor score models provide a more nuanced statistical view of the characteristics that drive individual concern for clusters of technologies. Similar models have been estimated for concern with each individual technology; eight regression equations linking normalized raw concern ratings to individual and household characteristics have been estimated. Similar correlations between characteristics and technologies in the same cluster are strong. A similar portrait of technology clusters and correlations to individual characteristics is revealed by the system of eight equations. For sake of brevity, these more detailed regression analyses are not presented here but are available from the corresponding author upon request.

Perhaps the most interesting comparison is between those respondents who have high levels of concern for

the cluster of technologies including artificial growth hormones, genetic modification, and irradiation (HGI) and the cluster featuring antibiotics and pesticides (ANTIPEST). Both clusters feature technologies that feature high raw levels of concern and technologies that have received considerable attention by policymakers and the media.

Several characteristics have significant correlations to the HGI and ANTIPEST factors where the correlations are of the opposite sign; such characteristics help identify the unique aspects of the profile of a typical respondent that is deeply concerned about each cluster of technologies. For example, female respondents have significantly higher HGI factor scores and significantly lower ANTIPEST factor scores than do males. A similar pattern holds for those who express a high degree of concern about how food is grown in other countries and for those whose highest educational achievement is a high school degree. Those respondents who are older than 65 hold the opposite pattern: On average they have lower scores for the HGI factor and higher scores for the ANTIPEST factor.

For several characteristics there exists a significant correlation to one factor but not to the other. For example, income level and race were correlated to factor scores of HGI, with higher concern for this technology cluster held by respondents with a lower income and of a minority racial group; these characteristics were not significantly correlated to ANTIPEST factor scores. Furthermore, those who regularly purchase organic food, read nutrition labels, grow home vegetable gardens, and have some college education have higher HGI factor scores, while these characteristics do not predict ANTIPEST factor scores. Respondents who frequent farmers' markets are more likely to have a higher ANTIPEST factor score, although this characteristics does not predict the HGI factor score.

Several characteristics have the same significant qualitative association with both HGI and ANTIPEST factors: Those who express a low degree of concern with the way food is processed in the United States and those who are less than 30 years old have lower factor scores for both HGI and ANTIPEST.

These correlates of concern for the HGI factor share several similarities with Misra et al.'s (1995) portrait of those who expressed concern about irradiation. In short, both studies found that women with less formal education and lower incomes tend to view irradiation as a more serious concern, although the present study finds the correlation to a factor in which irradiation is but one of three technologies that load heavily upon the factor.

The characteristics of the typical respondent with a higher OLDTECH factor score were distinct from those concerned with the other two technology clusters. For example, those concerned with the older technologies typically display less concern about how food is processed in the United States, do not read nutrition labels, are older than 65 years of age, are not adhering to any special dietary requirements (e.g., low-sodium diet), and have less than a college education.

Summary and Conclusion

For a representative sample of US consumers, we analyzed ratings of concern toward eight food production and processing technologies. We found that concern is highest for pesticides and artificial growth hormones, followed by concern about antibiotics, genetic modification, and irradiation. Correlations among ratings generally reflect differences in raw ratings, with similarly (differently) rated pairs of technologies displaying positive (negative) correlation. Factor analysis suggests that respondents' concern about a cluster of technologies, including artificial growth hormones, genetic modification, and irradiation (HGI), share a common unobservable component; this analysis similarly identified that concern for antibiotics and pesticides share a common factor (ANTIPEST), as do a cluster of older technologies, including artificial colors/flavors, preservatives, and pasteurization (OLDTECH).

Although the clusters featuring newer technologies (ANTIPEST and HGI) received similar raw concern ratings across the sample, the profiles of respondents who were highly concerned about each technology cluster were distinct. Those with high concern with the HGI cluster were more likely to be female, be between 30 and 65 years of age, have no children, be in the lowest income category, be of a minority racial group, have less than a college degree, express great concern for the way both domestic and imported food is grown and handled, purchase organic produce, read nutrition labels, and grow a vegetable garden. Those with high concern for the ANTIPEST cluster were also likely to express high concern for how domestic produce is grown and handled, but were less likely to be concerned with how imported produce is grown and handled. Furthermore, respondents with high concern for the ANTIPEST cluster were more likely to be male, to have formal education beyond high school, to be 65 years or older, and to shop at farmers' markets.

Respondents with a higher concern for the OLDTECH cluster were likely to be less concerned about

how food is processed in the United States, do not read nutrition labels, are older than 65 years of age, are not adhering to any special dietary requirements (e.g., low-sodium diet), and have less than a college education.

Results from models that explain the average raw ratings across technologies are similar to many of the previous findings in the literature about consumer concern toward food risks. For example, we found respondents that expressed high levels of concern about all eight technologies tended to be female, have less formal education, have lower household incomes, be middle-aged, and be from minority racial groups. Contrary to some previous literature, we found that respondents with young children have similar levels of concern as respondents with no children, while households with older children express less concern than childless households.

Our exploration of the models of factor scores for each technology cluster reveals considerable heterogeneity in how personal and household characteristics affect stated concern. We reveal a wealth of differential effects of characteristics across technologies clusters and show that variables that have little effect in explaining average concern toward food technologies may have discriminatory power in explaining relative ratings across technologies.

Analysis of the relative ratings may provide insight into market niches that may be more accepting of certain types of technologies. Significant work remains towards understanding the roots of the myriad of results presented above, particularly with regard to how various personal and household characteristics impact relative concerns for various technologies. Greater insights may be possible if theories of risk communication and response are brought to bear on the current empirical regularities.

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