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Consumer Food Safety Concerns and Fresh Produce Consumption

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The linear approximation of an almost ideal demand system model was used to measure the impacts of prices, expenditures, and consumer food safety concerns on the consumption of 14 major fresh produce categories in the United States for the period 1970–92. The change in fresh produce consumption due to food safety concerns was calculated. The results indicate that risk information has not had a significant impact on the consumption of most of the fresh produce items studied.

Key words: food safety concerns, fresh produce consumption, risk information

Introduction

Chemical residues in/on foods have become a growing concern for consumers [Food Marketing Institute (FMI) 1990; National Restaurant Association (NRA); Zind]. With the improvement of living standards, consumers have become increasingly concerned about health and general physical well-being. Moreover, the increased use of chemicals in agriculture (Taylor; Runge et al.) has heightened consumers' concerns regarding the health hazards of chemical residues in/on foods. The general public ranks pesticides and other chemical residues as the most serious food health hazard to society (FMI 1994). Risk information provided by the media and the enhanced ability to detect residues in food also have contributed to these deepening concerns. Past studies have shown that concerns about pesticides and nutrition have affected consumers' preferences and food consumption patterns, but little research has been conducted to quantify the effects of these concerns on the consumption of fresh produce items.

The objective of this study is to analyze the impacts of prices, expenditures, and consumer food safety concerns on the consumption of selected fresh fruits and vegetables in the U.S. from 1970 through 1992. We construct an information variable on food safety concerns and quantify its impacts on the consumption of selected fresh produce items. In addition, a test for determining weak separability between fresh produce and other foods, as well as between fresh fruits and vegetables, is performed. The 20 most commonly consumed fresh produce items (10 fresh fruits and 10 fresh vegetables, based on their per capita consumption) in the U.S. in the past decade were selected for this

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study. The 10 fresh fruits included watermelon, cantaloupe, honeydew melons, oranges, grapefruit, apples, bananas, grapes, peaches, and strawberries. The 10 fresh vegetables were broccoli, carrots, cauliflower, celery, lettuce, onions, tomatoes, cabbage, cucumbers, and green peppers. For estimation purposes, the fruits and vegetables were each aggregated into seven categories, defined in the data section of this article.

Food Safety Concerns and Changes in Consumption Patterns

Past studies have identified changes in consumer preferences and consumption patterns due to food safety concerns. Concern about chemical residues in/on foods is likely reflected in the increased demand for organic foods. A survey of shoppers from random sampling in New York State showed that 40% of the respondents usually or almost always purchase organic produce, and 33% are willing to pay a 100% premium for residue-free produce (Goldman and Clancy). Jolly et al. considered a random sample of 1,950 California residents in 1989, and found that 23% of the respondents usually looked for organic foods when shopping and the majority of the respondents were willing to pay premium prices for them—30¢ more for each pound of selected fruits and vegetables, 80¢ more per pound of chicken, and 90¢ more per pound of beef and pork and per dozen eggs.

Among various food products, fresh fruits and vegetables have received the most attention with respect to pesticides and other chemical residues. The results of one survey indicated that more than 80% of consumers were concerned about the possible presence of pesticides or other chemical residues on fresh produce (*The Packer*). Jolly et al. found that fruits and vegetables are the most frequently purchased organic foods. Although sales of fresh produce have experienced a rapid growth in recent years (Beamer and Preston), chemical residues continue to be a major consumer concern.

A number of studies have attempted to analyze the link between changes in consumption patterns and concerns about food safety. Brown and Schrader estimated the effects of consumer concerns regarding cholesterol on the consumption of shell eggs by using a log-linear model. An information index was constructed based on the number of related articles in medical journals published in the United States. Their results suggested that risk information about cholesterol had a substantial effect on shell egg consumption. Capps and Schmitz, using the information index developed by Brown and Schrader and a modified Rotterdam model, found that cholesterol risk information was a statistically significant determinant in the consumption of pork, poultry, and fish.

Smith, van Ravenswaay, and Thompson, with a similar objective, estimated the impact of negative media coverage of the heptachlor incident on the sales of Class I milk in Oahu, Hawaii, in 1982. (Heptachlor is a chemical preservative used in grains to avoid germ development.) They reported that the negative coverage had a significant impact on milk purchases. Chang and Kinnucan found that increased consumer awareness of the health hazard of cholesterol contributed to the secular decline in butter consumption in Canada during the 1966–87 period. Van Ravenswaay and Hoehn considered the effects of risk information regarding the presence of Alar. They modeled the demand for fresh apples in the New York City/Newark metropolitan area during the period 1980–89. Risk information was shown to have a significant impact on the demand for fresh apples. Payson estimated the effects of media coverage of food safety issues on the consumption of beef, pork, poultry, and seafood in the U.S. from 1937–91. A net negative effect of risk information was observed for beef and seafood, but not for poultry and pork. Such researchers as those noted above have made significant contributions to the literature in measuring the relationship between food safety concerns and food consumption.

The Information Variable

A typical approach in modeling the effects of risk information on food consumption has been the use of information variables. Several information indices have been constructed and used by Brown and Schrader; Chang and Kinnucan; van Ravenswaay and Hoehn; and Payson. Some of these indices reflect single concerns (e.g., cholesterol, Alar), while others reflect multiple concerns but have a single information source (e.g., medical journals). Risk information is assumed to affect food consumption by altering consumer perceptions and preferences due to health concerns. Risk information comes from various sources. In order to interpret the risk measure, the number and types of sources should be considered.

INF, the information variable of this study, is the number of net negative media coverage units (as determined by the nature[1] of information) each year regarding the health hazards of chemical residues in/on fresh produce. The units of coverage are comprised of the number of reports in newspapers, TV and radio broadcasts, newsletters, journals, and magazines. Each report is counted as one unit and is given equal weight. The nature of each report is determined by its title and content. Since the effects of negative and positive reports may offset each other, the net is obtained by subtracting the positive from the negative. It is anticipated that *INF* has negative effects on the consumption of fresh produce.

Data for the information variable are provided by DataTimes Corporation based in Oklahoma City. DataTimes is an information network whose database contains information from over 3,500 sources including more than 130 newspapers, magazines, journals, industry publications, company and business reports, and broadcast transcripts from CNN and National Public Radio. Data are collected by counting the number of related reports in the database each year.

The Model

The linear approximation of an almost ideal demand system (LA/AIDS) (Hayes, Wahl, and Williams; Green and Alston) is used in this study to estimate the parameters of the

[1] Information on produce can be of varying natures with regard to its impacts on consumer demand: negative, positive, and neutral. Negative information recognizes the health hazards of certain substances (such as chemical residues) in foods; therefore, it tends to discourage the consumption of foods which may contain those substances. Positive information includes generic advertising (e.g., media coverage on eating five servings of fruits and vegetables per day) and information that encourages food consumption. Neutral information does not provide a clear stand (for example, chemical residues under a certain level are not hazardous to health, but government testing is not reliable and no one knows the exact amounts of chemical residues in foods). In this study, the net effect of risk information is measured by subtracting the number of positive reports from the negative ones, and thus is denoted "net negative." The neutral information is discarded due to its uncertain nature.

demand for fresh fruits and vegetables. The LA/AIDS model represents a flexible complete demand system and possesses a functional form consistent with household budget data. It does not require additivity of the utility function. It satisfies the axioms of choice exactly and under certain conditions aggregates perfectly over consumers (Deaton and Muellbauer 1980a). Due to its advantages, the LA/AIDS model has been utilized in the analysis of both macro- and micro-demand systems and has been a popular tool for researchers (Deaton and Muellbauer 1980a; Hayes, Wahl, and Williams; Haden; Green and Alston; Eales and Unnevehr; Blanciforti, Green, and King; Gould, Cox, and Perali). The LA/AIDS model is specified as follows:

(1) $$W_i = \alpha_i + \sum_{k=1}^{n} C_{ik}\log(P_k) + \beta_i \log\left(\frac{Y}{P}\right),$$

where W_i is the budget share of good i, P_k is the price of good k, Y is per capita income or expenditure, and P is a suitable price index. Deaton and Muellbauer (1980a) suggest using Stone's price index whose linear approximation is defined as:

$$\ln(P) = \sum_{i=1}^{n} W_i \ln(P_i).$$

Eales and Unnevehr used $\ln(P) = \Sigma_j W_{jt-1}\ln(P_{jt})$ instead of Stone's index to avoid the simultaneity problem. However, the functional form test indicates that the Eales and Unnevehr version of Stone's index is not appropriate for this study. Therefore, we use $\Sigma_j W_{jt}\ln(P_{jt})$ here.

Since one objective of this study is to analyze the impacts of risk information on demand, a modified version of the AIDS model is used which incorporates the risk information as an intercept shifter. The approach used here follows that of Heien and Pompelli. In their study, the demographic effects were incorporated into the AIDS model by allowing the intercept to be a function of demographic variables. Therefore, in this study, the intercept term in equation (1) is defined as:

$$\alpha_i = \rho_{i0} + \rho_{i1} INF,$$

where INF represents risk information on produce.

Based on the results of a pretest for separability, share equations for fruits and vegetables are estimated in two separate demand systems using the model in equation (1). In the model, P_k represents the price of fruit or vegetable item k, and Y is the total per capita expenditure on the studied fruits (in the fruit system) and the studied vegetables (in the vegetable system). The definitions of other variables are as given earlier.

Adding-up, homogeneity, and Slutsky symmetry, respectively, can be imposed by restricting the parameters of the system as follows:[2]

(2) $$\sum_{i=1}^{n} \rho_{i0} = 1, \quad \sum_{i=1}^{n} \rho_{ij} = 0 \ (j = 1, 2), \quad \sum_{i=1}^{n} C_{ik} = 0, \quad \sum_{i=1}^{n} \beta_i = 0;$$

[2] Note that the homogeneity condition [equation (3)] is implied by the adding-up [equation (2)] and the symmetry [equation (4)] conditions, and therefore does not need to be imposed. The fruit and vegetable equations also were estimated unrestricted.

(3) $$\sum_{k=1}^{n} C_{ik} = 0;$$

(4) $$C_{ik} = C_{ki}, \quad i \neq k.$$

Marshallian and Hicksian measures of elasticities were computed from the estimated parameters using derivations by Chalfant[3] as follows:

$$\begin{aligned} E_{ii} &= -1 + C_{ii}/W_i - B_i, \\ E_{ij} &= C_{ij}/W_i - B_i(W_j/W_i), \\ S_{ii} &= -1 + C_{ii}/W_i + W_i, \\ S_{ij} &= C_{ij}/W_i + W_j, \end{aligned}$$

where E denotes Marshallian elasticities, and S denotes Hicksian elasticities. Expenditure elasticities were obtained through equation (5) below:

(5) $$\eta_i = 1 + B_i/W_i.$$

A procedure similar to that adopted by McGuirk et al. is used to calculate risk information elasticities in this study, i.e.:

(6) $$R_i = \rho_{i1}\left(\frac{INF}{W_i}\right),$$

where R_i denotes information elasticities, and ρ_{i1} denotes the coefficient estimates for risk information variables. Based on the calculated elasticities, the change in the consumption of each item due to food safety concerns is calculated through equation (7):

(7) $$\Delta X_i = R_i * X_i * (\Delta INF/INF),$$

where ΔX_i is the average annual per capita consumption change (decrease in consumption of item i incurred by risk information); R_i is from equation (6), which represents the demand elasticity of item i with respect to risk information (INF); X_i is the average annual per capita consumption of item i; and $\Delta INF/INF$ is the average annual percentage change in risk information. Equation (7) directly follows from the definition of demand elasticity, i.e.:

$$R_i = (\Delta X_i/X_i)/(\Delta INF/INF).$$

[3] Green and Alston show that $d\ln(P)/d\ln(P_j) = W_j + \Sigma_k W_k \ln(P_k)(d\ln(W)/d\ln(P_j))$. Since the $\Sigma_k W_k \ln(P_k)(d\ln(W)/d\ln(P_j))$ is small (less than 0.05 in absolute value in this study), Chalfant assumes this term equal to zero. Therefore, we assume $d\ln(P)/d\ln(P_j) = W_j$.

The demand system also was estimated using the Rotterdam model. As suggested by Alston and Chalfant, the Rotterdam model requires data similar to the AIDS model. The Rotterdam model might be more appropriate for some commodities than the AIDS model. For example, Alston and Chalfant's study showed that the Rotterdam model is more suitable for meat demand than the AIDS model. Likewise, the appropriateness of the Rotterdam model was tested in this study. However, when the Rotterdam model was used, the results of misspecification tests show that the Rotterdam functional form is not an appropriate representation of the fruit and vegetable demand systems we consider. Therefore, the LA/AIDS model is used in this study.

In another version of the model, a habit variable representing consumption habits and defined as the lagged budget share was incorporated into equation (1) as an intercept shifter. Again, the results of system misspecification tests indicated that the version of the model including the habit variable was not appropriate. Nevertheless, the results with regard to the impact of risk information on the demand from the version including the lagged budget share were similar to the results from the version that excludes the habit variable and which is presented in this study.

Test of Separability

In demand analysis, researchers often are interested in consumer demand for one commodity or a commodity subgroup. In a two-stage (conditional) demand analysis, weak separability frequently is assumed as a maintained hypothesis. However, in most empirical studies in which weak separability has been tested, this hypothesis was rejected (Pudney). Therefore, a test should be performed when modeling conditional demand to determine if weak separability holds. In his analysis of the structure of consumer preferences, Pudney presents alternative forms of separability. The restrictions that can be used for testing weak separability are provided in Moschini, Moro, and Green, and in Sellen and Goddard. The Moschini, Moro, and Green findings suggest that foods are separable from the nonfood group, meats are separable from other foods, and meats are separable from nonmeat groups. In this study, the approach proposed by Moschini, Moro, and Green is used to test the separability of fresh produce from all other foods, and fresh fruits from fresh vegetables.

Data and Estimation Procedure

Considering the temporal nature of risk information, quarterly data may be more preferable when measuring the impacts of risk information. However, after personally consulting with staff of the U.S. Department of Agriculture (USDA), the Food Marketing Institute (FMI), the Bureau of Economic Analysis (BEA), the Produce Marketing Association (PMA), and the Bureau of Labor Statistics (BLS), we found that quarterly data on consumption are not available. Consequently, annual data from 1970 through 1992 are used to estimate equation (1). Data sources for consumption, prices, and expenditures include the USDA/Economic Research Service (1992, 1993a,b), Food For Less (retail food supermarket), Putnam and Allshouse, and *Supermarket Business*. Data for the risk information variable are from DataTimes Corporation.

To increase the degrees of freedom in this study, similar fruits and vegetables are combined in order to decrease the number of included commodities. For vegetables: broccoli, cauliflower, and cabbage are aggregated as they are all in the crucifer family; similarly, celery and lettuce are studied as one group since both are in the foliage family. For fruits: watermelon, honeydew, and cantaloupe are combined as they all belong to the wine crops (melons); oranges and grapefruit are combined and represent the citrus family.

Test of Endogeneity

The expenditure variable might not be an exogenous variable in the model under certain assumptions. Ignoring the correlation between the expenditure variable and the error term may lead to estimates that are biased and inconsistent (Edgerton). In this study, the endogeneity of income was determined by applying the Durbin-Wu-Hausman (DWH) test as suggested by LaFrance. Using this method, disposable income generally is used as an instrumental variable in the model (Edgerton; McGuirk et al.). The results of the DWH test indicate that the null hypothesis of no correlation between the error term and expenditure variable cannot be rejected for the fresh fruits model, but is rejected for the fresh vegetables model at the $\alpha = 0.05$ level. To correct for endogeneity in the vegetable model, the approach used by Edgerton is employed here. In this approach, the predicted value of expenditure is added to the LA/AIDS model [equation (1)]. The predicted value is obtained by regressing expenditure on disposable income and vegetable prices.

System Misspecification Tests

The assumptions of normal distribution, no autocorrelation, parameter stability, homoskedasticity, and the appropriateness of functional form were tested using the system misspecification tests as suggested by McGuirk et al. The assumption of normality holds at the 5% significance level. The assumptions of appropriateness of functional form, independence, stability, and homoskedasticity are tested through joint conditional mean and joint conditional variance tests. The results show that these assumptions cannot be rejected at the 2% significance level for the vegetable model and the 5% significance level for the fruit model.

The seemingly unrelated regression (SUR) method of estimation is used to estimate the model in equation (1), with the symmetry condition imposed.[4] Because the produce expenditure shares (W_i) sum to one, the two demand systems composed of expenditure share equations for the seven vegetable groups and seven fruit groups would be singular. Therefore, the last equation (green pepper in the vegetable system and strawberries in the fruit system) was dropped to estimate the equations as a system (Hays, Wahl, and

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[4] The Wald test was used to test the null hypothesis of whether the symmetry and homogeneity restrictions hold. The results indicate that both symmetry and homogeneity hold for vegetables, but not for fruits, at the $\alpha = 0.01$ level. However, the symmetry restriction was imposed for both the fruit and vegetable models (see footnote 2), as homogeneity and symmetry are implied by utility maximization and homogeneity is required for the homogeneity of the cost function which underlies the AIDS model (Deaton and Muellbauer 1980b). The model in equation (1) also was estimated unrestricted. The results from the unrestricted model gave a similar pattern of elasticities of quantity demanded with respect to prices and risk information compared to the restricted form.

Williams). The coefficients of the last equations can be calculated from the adding-up restriction. Here, we dropped another equation and reestimated the system in order to determine the parameters and the standard errors of the last equation. The results are the same as calculating the parameters of the last equations from the adding-up condition. Moreover, note that the measure of risk information is unobservable. Therefore, the data for the risk information variable (*INF*) may contain errors of measurement, which may bias the parameter estimates (Gao and Shonkwiler).

Results

The separability restrictions were tested by using the log-likelihood ratio test as suggested in Moschini, Moro, and Green. The first hypothesis—that fresh fruits are separable from fresh vegetables—failed to be rejected at the $\alpha = 0.05$ level. The second and third hypotheses, respectively—that fruits are separable from the meats group and from the cereal and dairy groups, and that vegetables are separable from the meats group and from the cereal and dairy groups—could not be rejected at the $\alpha = 0.025$ level. The existence of multicollinearity among the risk information and other variables of the model was also tested for each of the fruit and vegetable categories investigated. A commonly used rule to measure the severity of multicollinearity is to look at the size of the correlation coefficient between the values of two regressors. If the correlation coefficient is greater than 0.8 or 0.9, then multicollinearity is a serious problem (Judge et al.). In this study, none of the correlation coefficients among risk information and other variables were greater than 0.6, suggesting that multicollinearity did not pose a serious problem.

The Vegetable Model

Parameter estimates for vegetables are reported in table 1. The own-price parameters are statistically significant for five of the seven equations. However, cross-price effects are mixed; among the 42 cross-price parameters, 24 are statistically significant. Based on the estimated parameters, Marshallian and Hicksian demand elasticities for these vegetables are calculated (table 2). A strong substitute relationship based on the magnitude and significance of elasticities is shown between demand for carrots and price of crucifers. The demand for carrots is also elastic with respect to its own price. All expenditure elasticities indicate that vegetables are normal goods. All expenditure elasticities carry signs that are consistent with what is expected from economic theory, and only the expenditure elasticity for foliage is not statistically significant.

Risk information (*INF*) shows a small negative impact on the budget shares of crucifers, carrots, and foliage (table 1). Although only the risk information parameter for foliage is negative and statistically significant, this does not necessarily indicate economic insignificance (McCloskey and Ziliak). The elasticities of demand for various vegetables with respect to risk information show only a very small impact of *INF* on vegetable consumption. Among all risk information elasticities for vegetables, the foliage group shows the largest negative effect on demand (table 2). Moreover, risk information elasticities show a positive effect on onions, tomatoes, cucumbers, and green

Table 1. Parameter Estimates for Seven Fresh Vegetable Groups Using an LA/AIDS Model, 1970–92

	Dependent Variable (the budget share of per capita consumption)						
Indep. Variable	Crucifers[a]	Carrots	Foliage[b]	Onions	Tomatoes	Cucumbers	Green Peppers
Price of:							
Crucifers[a]	0.109**	-0.044**	-0.042**	-0.009	-0.011	0.010	-0.014
	(0.020)	(0.014)	(0.014)	(0.008)	(0.010)	(0.010)	(0.010)
Carrots	-0.044**	0.006	-0.027**	0.007	0.012	0.027**	0.019*
	(0.014)	(0.022)	(0.009)	(0.007)	(0.014)	(0.012)	(0.010)
Foliage[b]	-0.042**	-0.027**	0.215**	-0.060**	-0.038**	-0.002	-0.045**
	(0.014)	(0.009)	(0.034)	(0.010)	(0.007)	(0.006)	(0.010)
Onions	-0.009	0.007	-0.060**	0.097**	-0.013**	-0.015**	-0.006
	(-0.008)	(0.007)	(0.010)	(0.006)	(0.006)	(0.006)	(0.006)
Tomatoes	-0.011	0.012	-0.038**	-0.013**	0.083**	-0.014	-0.019**
	(-0.010)	(0.014)	(0.007)	(0.006)	(0.012)	(0.010)	(0.007)
Cucumbers	0.010	0.027**	-0.002	-0.015**	-0.014	0.016	-0.022**
	(0.010)	(0.012)	(0.006)	(0.006)	(0.010)	(0.013)	(0.008)
Green Peppers	-0.014	0.019*	-0.045**	-0.006	-0.019**	-0.022**	0.087**
	(0.010)	(0.010)	(0.010)	(0.006)	(0.007)	(0.008)	(0.009)
Expenditure[c]	0.077	-0.018	-0.234	0.052	0.017	-0.007	0.112**
	(0.059)	(0.037)	(0.151)	(0.044)	(0.031)	(0.024)	(0.047)
Risk Information	-0.0001	-3.9×10^{-6}	-0.0011**	0.0003	0.0001	0.0003**	0.0005**
	(0.0003)	(0.0002)	(0.0006)	(0.0002)	(0.0001)	(0.0001)	(0.0002)
R^2	0.86	0.89	0.83	0.90	0.95	0.84	0.90

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels, respectively. Numbers in parentheses are standard errors. The system $R^2 = 0.98$.

[a] Crucifers represent broccoli, cabbage, and cauliflower.

[b] Foliage represents celery and lettuce.

[c] Expenditure denotes per capita real expenditure on the seven vegetable groups.

peppers. Note that in this study, the risk information is an aggregate measure and does not pertain to any particular vegetable. Therefore, as consumers' awareness of risks associated with certain produce items increases, they may reduce their consumption of those vegetables and substitute others in their diet. Consequently, a positive impact of risk information on certain vegetables that are perceived as less hazardous may be observed as consumers substitute those vegetables for the ones targeted by the risk information.

The change in the consumption of each vegetable due to safety concerns is calculated through equation (7). The results of these calculations are reported in table 3. The mean percentage loss for the three vegetable categories with negative risk information elasticities (crucifers, carrots, and foliage) is 0.07, with the largest loss occurring in the foliage family (0.036 pounds/person/year). The per capita loss in the consumption of each of these three vegetable groups is less than one pound per year.

Table 2. Marshallian and Hicksian Demand Elasticities for Seven Fresh Vegetable Groups, 1970–92

	Dependent Variable (per capita consumption of:)						
Indep. Variable	Crucifers	Carrots	Foliage	Onions	Tomatoes	Cucumbers	Green Peppers
MARSHALLIAN:							
Price of:							
Crucifers	-0.038	1.334**	-0.039	-0.115	-0.125	0.175	-0.281**
	(0.190)	(0.190)	(0.047)	(0.074)	(0.101)	(0.160)	(0.123)
Carrots	-0.471**	-1.653**	-0.022	0.024	0.103	0.439**	0.114
	(0.142)	(0.289)	(0.033)	(0.063)	(0.131)	(0.196)	(0.118)
Foliage	-0.716**	-0.993**	-0.271	-0.652**	-0.433**	0.010	-0.104
	(0.283)	(0.249)	(0.172)	(0.173)	(0.147)	(0.196)	(0.257)
Onions	-0.180*	-0.250**	-0.070	-0.289**	-0.146**	-0.229**	-0.226**
	(0.109)	(0.116)	(0.049)	(0.065)	(0.068)	(0.106)	(0.095)
Tomatoes	-0.186	-0.258	-0.031	-0.148**	-0.232**	-0.209	-0.336**
	(0.115)	(0.186)	(0.040)	(0.059)	(0.116)	(0.165)	(0.099)
Cucumbers	0.050	0.070	0.028	-0.144**	-0.139	-0.727**	-1.319**
	(0.099)	(0.160)	(0.025)	(0.049)	(0.095)	(0.214)	(0.094)
Green Peppers	-0.196**	-0.272*	-0.055	-0.086	-0.190	-0.344**	0.843**
	(0.112)	(0.141)	(0.039)	(0.058)	(0.076)	(0.137)	(0.113)
Expenditure	1.737**	2.022**	0.461	1.410**	1.163**	0.885**	2.241**
	(0.562)	(0.493)	(0.348)	(0.349)	(0.294)	(0.385)	(0.519)
Risk Info	-0.005	-0.007	-0.014**	0.012	0.005	0.029**	0.031**
	(0.013)	(0.012)	(0.007)	(0.008)	(0.007)	(0.010)	(0.011)
HICKSIAN:							
Price of:							
Crucifers	0.145	1.547**	0.009	0.033	-0.002	0.268*	-0.045
	(0.186)	(0.187)	(0.032)	(0.066)	(0.099)	(0.158)	(0.114)
Carrots	-0.339**	-1.500**	0.013	0.131**	0.191	0.506**	0.284**
	(0.135)	(0.286)	(0.020)	(0.057)	(0.129)	(0.193)	(0.111)
Foliage	0.038	-0.115	-0.071	-0.040	0.072	0.394**	-0.063
	(0.130)	(0.117)	(0.077)	(0.078)	(0.068)	(0.093)	(0.115)
Onions	0.040	0.007	-0.012	-0.110**	0.002	-0.116	0.058**
	(0.079)	(0.095)	(0.023)	(0.047)	(0.055)	(0.090)	(0.067)
Tomatoes	-0.002	-0.044	0.017	0.001	-0.110	-0.116	-0.099
	(0.099)	(0.180)	(0.017)	(0.046)	(0.112)	(0.160)	(0.083)
Cucumbers	0.158*	0.195	0.056**	-0.057	-0.067	-0.672**	-0.180**
	(0.093)	(0.158)	(0.013)	(0.044)	(0.094)	(0.213)	(0.089)
Green Peppers	-0.039	-0.089	-0.013	0.041	-0.085	-0.264**	0.046
	(0.098)	(0.133)	(0.024)	(0.048)	(0.071)	(0.130)	(0.102)

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels, respectively. Numbers in parentheses are standard errors. Refer to notes to table 1 for definitions of crucifers, foliage, and expenditure variables.

Table 3. Change in Annual Per Capita Consumption of Fresh Vegetables and Fruits Due to Risk Information

Vegetables	Mean Consump. (lbs.)	Change (lbs.)	Percent Change (%)	Fruits	Mean Consump. (lbs.)	Change (lbs.)	Percent Change (%)
Crucifers	12.29	-0.0049	-0.040	Melons	21.40	-0.0017	-0.008
Carrots	6.71	-0.0038	-0.056	Citrus	20.37	-0.0005	-0.002
Foliage	31.84	-0.0357	-0.112	Apples	18.05	-0.0066	-0.037
Onions	12.47	0.0120	0.096	Bananas	21.75	-0.0002	-0.001
Tomatoes	13.70	0.0055	0.040	Grapes	5.14	0.0136	0.264
Cucumbers	3.99	0.0093	0.232	Peaches	5.68	0.0045	0.080
Green Peppers	3.42	0.0085	0.248	Strawberries	2.46	-0.0043	-0.176

Note: Refer to notes to table 1 for definitions of crucifers and foliage; refer to notes to table 4 for definitions of melons and citrus.

The Fruit Model

Parameter estimates for fruits are presented in table 4. Own-price exhibits a significant effect in five equations (melons, citrus, apples, grapes, and strawberries). As with the vegetable model, among the 42 cross-price parameters, only 24 are statistically significant, indicating that the budget shares of only some fruits significantly depend on the prices of other fruits. Expenditure shows a statistically significant effect in the share equations for citrus, apples, grapes, and strawberries.

The calculated Marshallian and Hicksian demand elasticities for fruits are reported in table 5. The demand for citrus, bananas, grapes, and peaches is elastic and significant with respect to their own prices. Among the studied fruits, some strong cross-price effects are observed. A strong substitute relationship based on the magnitude of Hicksian elasticities is shown between demand for grapes and price of bananas, demand for peaches and price of bananas, and demand for strawberries and the prices of citrus and grapes. Strong complementary relationships are observed between demand for strawberries and the prices of apples and bananas. All expenditure elasticities are positive (and statistically significant), indicating that the studied fruits are normal goods. Moreover, expenditure elasticities are greater than one for melons, citrus, grapes, peaches, and strawberries.

Risk information shows a similar effect on fruits as on vegetables. The effect of risk information is statistically insignificant (except for citrus and strawberries) and very small in all equations (table 4). While the risk information parameters reflect a negative impact on the budget shares of melons, citrus, apples, bananas, and strawberries, a positive impact is shown on grapes and peaches. Again, consumers may be aware of the risk information news regarding specific fruits and shift their consumption to others that they perceive to be harmless. Similar to vegetables, the magnitudes of the risk information elasticities for fruits are very small and statistically not significant.

The change in per capita consumption of fruits due to risk information is shown in the right-hand side of table 3. The loss of consumption is indicated by the negative change

Table 4. Parameter Estimates for Seven Fresh Fruit Groups Using an LA/AIDS Model, 1970–92

	Dependent Variable (the budget share of per capita consumption)						
Indep. Variable	Melons[a]	Citrus[b]	Apples	Bananas	Grapes	Peaches	Straw-berries
Price of:							
Melons[a]	0.072**	-0.002	-0.009	0.015	-0.064**	-0.020	0.009*
	(0.007)	(0.010)	(0.012)	(0.010)	(0.011)	(0.012)	(0.004)
Citrus[b]	-0.002	0.099**	0.020	-0.038*	-0.057**	-0.072**	0.050**
	(0.010)	(0.026)	(0.021)	(0.021)	(0.020)	(0.026)	(0.010)
Apples	-0.009	0.020	0.076*	-0.082**	0.043	0.021	-0.069**
	(0.012)	(0.021)	(0.036)	(0.022)	(0.028)	(0.026)	(0.009)
Bananas	0.015	-0.038*	-0.082**	-0.041	0.133**	0.099**	-0.085**
	(0.010)	(0.021)	(0.022)	(0.031)	(0.023)	(0.022)	(0.014)
Grapes	-0.064**	-0.057**	0.043	0.133**	-0.070*	-0.042	0.057**
	(0.010)	(0.020)	(0.028)	(0.023)	(0.038)	(0.029)	(0.010)
Peaches	-0.020	-0.072**	0.021	0.099**	-0.042	-0.002	0.016
	(0.012)	(0.026)	(0.026)	(0.022)	(0.029)	(0.037)	(0.010)
Strawberries	0.009*	0.050**	-0.069**	-0.085**	0.057**	0.016	0.023*
	(0.004)	(0.010)	(0.009)	(0.014)	(0.010)	(0.010)	(0.010)
Expenditure[c]	0.018	-0.501**	-0.138**	-0.025	0.504**	0.073	0.068**
	(0.017)	(0.028)	(0.050)	(0.028)	(0.053)	(0.047)	(0.011)
Risk Information	-1.3×10^{-5}	-0.0004*	-0.0002	-3.5×10^{-6}	0.0007	0.0002	-0.0002*
	(0.0002)	(0.0002)	(0.0004)	(0.0003)	(0.0004)	(0.0004)	(0.0001)
R^2	0.91	0.98	0.68	0.79	0.92	0.32	0.96

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels, respectively. Numbers in parentheses are standard errors. The system $R^2 = 1.00$.

[a] Melons represent watermelon, honeydew, and cantaloupe.

[b] Citrus represents oranges and grapefruit.

[c] Expenditure denotes per capita real expenditure on the seven fruit groups.

in per capita consumption. The range of percentage loss for these fruit groups is from 0.001 for bananas to 0.176 for strawberries, with a mean percentage loss for fruits of 0.05%. The largest loss occurs in the consumption of apples, which decreased by 0.007 pounds/person/year. Similar to vegetables, the per capita loss in the consumption of each fruit due to risk information is less than one pound a year.

Because there currently is no published research on the impact of risk information on the consumption of the fruits and vegetables examined here (except for apples), it is difficult to make any meaningful comparisons with other studies. Moreover, the results of other available studies are mixed. For example, risk information was found to have a significant impact on the demand for eggs (Brown and Schrader); and apples (van Ravenswaay and Hoehn), but not beef (Capps and Schmitz); beef, seafood, pork, and poultry (Payson); milk (Smith, van Ravenswaay, and Thompson), butter, and salad oil and margarine and shortening (Chang and Kinnucan). Further, it was found that risk information does not have a significant impact on the consumption of oysters and shrimp (Lin and Milon) and cranberries (Brown).

Table 5. Marshallian and Hicksian Demand Elasticities for Seven Fresh Fruit Groups, 1970–92

	Dependent Variable (per capita consumption of:)						
Indep. Variable	Melons	Citrus	Apples	Bananas	Grapes	Peaches	Straw-berries
MARSHALLIAN:							
Price of:							
Melons	-0.035	0.315**	0.003	0.092	-0.849**	-0.319**	0.080
	(0.091)	(0.042)	(0.044)	(0.056)	(0.095)	(0.149)	(0.099)
Citrus	-0.085	-1.028**	0.187**	-0.174	-1.423**	-1.124**	0.760**
	(0.128)	(0.110)	(0.083)	(0.108)	(0.182)	(0.314)	(0.222)
Apples	-0.195	-0.064	-0.586**	-0.409**	-0.797**	0.015	-1.941**
	(0.183)	(0.106)	(0.144)	(0.128)	(0.280)	(0.390)	(0.227)
Bananas	0.164	0.053	-0.207**	-1.199**	0.331	1.082**	-2.165**
	(0.140)	(0.091)	(0.084)	(0.165)	(0.213)	(0.290)	(0.299)
Grapes	-0.909**	-0.296**	0.218**	0.735**	-2.092**	-0.647*	1.088**
	(0.146)	(0.087)	(0.097)	(0.128)	(0.303)	(0.345)	(0.225)
Peaches	-0.288*	-0.094	0.118	0.546**	-0.686**	-1.105**	-0.764**
	(0.171)	(0.122)	(0.101)	(0.124)	(0.257)	(0.494)	(0.236)
Strawberries	0.106*	0.035	-0.229**	-0.456	0.289**	0.161	0.438*
	(0.062)	(0.047)	(0.035)	(0.077)	(0.085)	(0.130)	(0.241)
Expenditure	1.242**	1.079**	0.497**	0.866**	5.223**	1.937**	2.504**
	(0.230)	(0.126)	(0.182)	(0.154)	(0.441)	(0.592)	(0.248)
Risk Info	-0.0009	-0.0003	-0.0045	-0.0001	0.033	0.010	-0.022
	(0.011)	(0.006)	(0.009)	(0.008)	(0.020)	(0.026)	(0.011)
HICKSIAN:							
Price of:							
Melons	0.056	0.394**	0.039	0.156**	-0.466**	-0.177	0.263**
	(0.092)	(0.042)	(0.044)	(0.055)	(0.092)	(0.151)	(0.099)
Citrus	0.193	-0.786**	0.299**	0.020	-0.250	-0.690**	1.322**
	(0.130)	(0.115)	(0.078)	(0.113)	(0.165)	(0.333)	(0.230)
Apples	0.146	0.233**	-0.450**	-0.172	0.638**	0.546*	-1.253**
	(0.164)	(0.095)	(0.130)	(0.117)	(0.233)	(0.331)	(0.207)
Bananas	0.393**	0.253**	-0.115	-1.040**	1.296**	1.440**	-1.702**
	(0.138)	(0.093)	(0.079)	(0.169)	(0.196)	(0.277)	(0.310)
Grapes	-0.760**	-0.168*	0.277**	0.838**	-1.468**	-0.416	1.387**
	(0.149)	(0.088)	(0.101)	(0.127)	(0.319)	(0.363)	(0.222)
Peaches	-0.190	-0.009	0.157*	0.614**	-0.274	-0.952**	0.433*
	(0.162)	(0.117)	(0.095)	(0.076)	(0.239)	(0.468)	(0.226)
Strawberries	0.162**	0.083*	-0.206**	-0.417**	0.525**	0.249*	-0.449*
	(0.061)	(0.046)	(0.034)	(0.076)	(0.084)	(0.130)	(0.240)

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels, respectively. Numbers in parentheses are standard errors. Refer to notes to table 4 for definitions of melons, citrus, and expenditure variables.

Summary and Conclusions

This study measures the impact of prices, expenditures, and food safety concerns on the budget shares of the most popular fresh fruits and vegetables. An information variable that incorporates risk information regarding the health hazard of chemical residues, as well as any positive information such as generic promotional advertising with regard to fresh produce, is used to measure the impact of consumers' food safety concerns. Two tests are performed to check for separability between fresh produce and all other foods, and between fresh fruits and fresh vegetables. An LA/AIDS model is used in this study. In addition, the change in fresh produce consumption due to safety concerns is calculated.

The results of the separability tests indicate that fresh produce and other foods can be treated as separable commodity groups, and fresh fruits and fresh vegetables can be studied as two separate groups. The elasticities suggest that the consumption of some of the fresh produce items examined here are affected more by their own price and expenditure than by the prices of other fresh produce. Statistically, group-level expenditure exhibits a significant impact on six vegetables and all fruits.

The magnitudes of the risk information elasticities indicate that the impact of risk information on consumption is very small and statistically insignificant for almost all of the studied produce categories. Nevertheless, one should not ignore the impact of risk information on consumption, as statistical insignificance does not always imply economic insignificance (McCloskey and Ziliak). Therefore, consumption losses as a result of risk information are calculated in this analysis. The calculations show an average loss of 0.07% in the consumption of the studied vegetables and a 0.05% loss in the consumption of the studied fruits. Moreover, demand elasticities with respect to risk information obtained from the results of this study show varying signs which may indicate different consumer responses to risk information for each produce item. In general, it can be concluded from the results of this study that the economic variables (expenditure and prices) have a larger impact on the consumption of the studied vegetables and fruits than the noneconomic variables such as risk information.

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