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University of Minnesota
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Universita degli Studi di Padova
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SESSION IV: FOOD MARKETING AND THE ENVIRONMENT

PAPER 3: A HEDONIC PRICE STUDY OF PESTICIDES IN FRUITS AND VEGETABLES

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A Hedonic Price Study of Pesticides in Fruits and Vegetables

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Sommario

Questo studio utilizza la stima di una regressione edonica per determinare la volonta dei consumatori di pagare per ridurre la quantita dei residui di pesticidi in quindici tipi di frutte e verdure. Una caracteristica particolare di questo studio e luso dei dati del Administrazione Americana per alimenti e medicine che misurano la quantita di pesticidi ingerita dalla popolazione americana attraverso il consumo di alime crudi o preparati. I risultati indicano che i consumatori sarebbero inclinati a pagare circa 8 centesimi per libbra per ridurre la quantita di pesticidi delluno per mille nelle frutte e verdure preparate che loro consumano.

Abstract

This study estimates a hedonic price equation to assess consumers' willingness-to-pay for reduction in pesticide residues in fifteen fruits and vegetables. A unique feature of the study is its employment of the FDA's Total Diet Study data which attempts to measure actual pesticide ingestion by the American public in table-ready or prepared foods. The results indicate that consumers would be willing to pay approximately $.08 per pound to reduce pesticides by one part per million in the prepared fruits and vegetables that they consume.

Uno studio edonico dei prezzi dei pesticidi per frutta e verdure

Frances Antonovitz e Donald J. Liu

Since the 1960's, consumers in the U.S. have become increasing more aware and concerned about pesticides in their food supply. In response to growing concerns about the environment in general, the U.S. government created the Environmental Protection Agency (EPA) in 1970 which, among its many mandates, called for more research emphasizing human health in pesticide regulation. However, recent surveys have continued to report consistently high levels of concern about pesticides. For example, Zind finds from the Packer's Fresh Trend 1990 survey that 86% of the respondents expressed concern about chemical residues on fresh produce. Zellner and Degner report the results from a national survey which found that 59% of consumers rated pesticide residues as a high concern and 24% as a medium concern. In addition, consumers are generally more concerned about the food risk associated with pesticide residues and environmental contaminants than they are about bacterial contamination of food or foodborne disease (Kramer).

In contrast, scientific experts evaluate food risks differently and consider disease caused by microorganisms as a more serious health problem (Kramer). The Food and Drug Administration's (FDA) pesticide monitoring program began in 1961 and has undergone continual refinement since its inception (Gunderson). The FDA has provided annual reports about this program since 1987 and concluded that the levels of pesticide residues found in the U.S. food supply are generally well below safety limits given to them by the EPA. For example, one aspect of the FDA's pesticide monitoring program involves the sampling of individual lots of domestically produced and imported foods and analysis for pesticide residues. In 1993, for the domestic surveillance of fruits and vegetables, 59% and 70% of the samples, respectively, had no pesticides detected, 39% and 28% had detected pesticides but not at violative levels, and less than 2% of the samples contained violative residues (see FDA). Results were quite similar for imported produce with fewer than 4% of the samples containing violative residues. (FDA)

A number of studies over the past ten years have attempted to measure consumers' willingness-to-pay for pesticide-free food using a variety of techniques including consumer surveys and contingent valuations. However, the results of these studies are quite varied. This study will provide a review of the various techniques used along with the results obtained. We will then discuss a commonly used method based on the hedonic price model which has not yet been used to address the pesticide issue. The Total Diet Study, a unique data set which gives approximate measures of the actual pesticide risk in a typical American diet, will be used to estimate the hedonic price of pesticides in fruits and vegetables and consumers' willingness-to-pay for pesticide-free produce.

Related Studies

Several recent studies have obtained estimates of consumers' willingness-to-pay to reduce pesticides in a particular food item by conducting surveys. Van Ravenswaay and Hoehn (1991b), using a national sample, surveyed consumers and calculated their willingness-to-pay for additional information about pesticide levels in apples. They found that consumers were willing to pay an additional $.236 per pound for labels indicating either "no detectable pesticide residues" or "no pesticide residues above federal limits," and $.375 per pound for a label indicating "no pesticide residue." Buzby, Skees and Ready combined national telephone and mail surveys and used two different methods (payment card and dichotomous choice) to examine the willingness-to-pay for pesticide reduction by U.S. grapefruit consumers. Two payment card methods resulted in willingness-to-pay estimates of $.15 and $.19 per grapefruit (with an original price of $.50) while the dichotomous choice methods resulted in mean willingness-to-pay estimates of $.67 and $.69 per grapefruit. Averaging over the estimates, the authors concluded that consumers were willing to pay 93% in excess of the purchase price of each grapefruit to reduce their pesticide risk over a lifetime.

While the above survey studies focused on a particular food item, others have attempted to measure willingness-to-pay for pesticide reduction in all produce. Eom hypothesized that while consumers may be concerned about the pesticide level in their food, they must make choices when they possess incomplete information about the actual health risk associated with different levels of pesticides. He developed a random utility model for describing discrete choices for safer produce and surveyed shoppers in the Raleigh/Cary area in North Carolina. About 65% of consumers surveyed expressed a willingness to purchase residue-tested produce even though it cost $.35 more on average. With an average per unit price of untested produce of $.88 per unit, Eom calculated that consumers were willing to pay, on average, $.75 - $.80 more per unit for residue-tested produce. In contrast, three studies found that consumers were unwilling to pay much, if anything, for pesticide-free produce. Ott surveyed shoppers in the Atlanta area and found that 33.9% of the respondents were unwilling to pay a higher price to obtain pesticide-free produce while 56.5% would be willing to accept only a 5% increase in price. Only 9.6% were willing to pay 10% more. These small price premiums for pesticide-free produce appear to be in line with Ott's additional finding that the majority of consumers would be unwilling to accept produce of a lower quality with 61.5% unwilling to accept any cosmetic defects and 88.4% unwilling to accept any insect damage. Similarly, in a mail survey of Georgia consumers, Ott, Huang, and Misra found that consumers were generally unwilling to pay anything extra or pay only a small price premium for tested and certified pesticide-free produce. In his Michigan survey of 600 households, Atkin found the similar result that the median additional willingness-to-pay for pesticide-free produce was about 5%. The Michigan result indicates that 66% were willing to pay for food products grown without pesticides and/or chemicals: with 23% willing to pay 5% more, 21% willing to pay 10% more, and 17% willing to pay more that 10%.

Consumers' perceptions toward organic food items have also been exploited to examine the value of pesticide-free produce. Hammitt conducted a pilot study in which 23 conventional-food and 22 organic-food consumers were administered a brief questionnaire in order to assess their willingness-to-pay for organic produce (which is frequently regarded as pesticide-free). Similar to the findings of Ott, Ott, Huang and Misra, and Atkin, the median price premium for organic produce was found to be only 5% for the conventional-food consumers.

We could characterize another group of studies measuring the willingness-to-pay for food safety into the experimental economics category. In these studies, the researchers elicit information from respondents by placing them within a hypothetical market environment. In addition, the experimenter actually observes the behavior of the participants who are following a set of instructions. Proponents of this method suggest that since respondents are often put in situations where they must actually purchase or consume the food, their responses are more honest, accurate, and less biased. Of course, the conducting of these types of experiments is costly with the tendency to have only small and/or biased sample respondents. Baker and Crosbie used conjoint analysis to study individual consumer preference functions for fresh apple products in an experimental market setting in the San Francisco Bay Area. They suggested conjoint analysis as one method to combat the problem of consumer heterogeneity (or consumer aggregation) affecting some of the previous research results. Consumers were segmented into three groups based on similarity of their preference functions. The results indicate that all segments were willing to pay a substantial price premium for the government to certify that apples met established safety standards. Even individuals in the segment willing to pay the least for certification were still willing to pay an additional $.225 per pound. However, it is interesting to point out again that, although the majority of respondents (84%) favored reducing pesticide use and attached a price premium for pesticide-free apples, they were willing to pay for this premium only if problems such as cosmetic defects and insect damage did not occur.

Some studies have attempted to measure in an objective manner the amount of information available to consumers about different health risks and its impact on consumers' consumption of the afflicted commodities. Brown and Schrader attempted to measure consumers' awareness of cholesterol and its impact on the demand for eggs by forming a cholesterol information index. It was based upon the number of citations in medical journals discussing the implications of cholesterol (sometimes negative and sometimes positive) on human health. They found evidence to suggest that this index served as a reasonable proxy for information reaching consumers and affecting their egg consumption decisions. Adapting the approach to pesticide research, Van Ravenswaay and Hoehn (1991a) constructed a similar information index by counting the number of articles in the New York Times which contained the words "Alar" or "daminozide" (the carcinogenic pesticide used in apple production discussed in the 60 Minutes television program in February 1989) between 1984 and 1989. They found that consumers were willing to pay for Alar-free apples and that these estimates increased during the study period -- from $.115 per pound in 1984 to $.313 per pound in 1989.

Other authors have approximated consumers' willingness-to-pay for pesticide-free food by estimating price premiums paid for organic foods. Van Ravenswaay provides an excellent review of these studies. However, there are problems associated with this approach. First, while there is evidence that consumers may think that organic foods are grown without pesticides (Wohl, Van Ravenswaay, and Hoehn), this may not be the case and certainly some consumers do not believe this to be the case. Second, no more than 10%, and possibly as few as 5%, of consumers are frequent purchasers of organic food (Van Ravenswaay). Last, it may be the case that organic-food purchasers have different preferences and hence, are willing to pay more than conventional food purchasers for pesticide-free food. For example, in Hammitt's pilot study described earlier, the median additional willingness-to-pay of the 22 organic-food consumers for pesticide-free produce was 50% as opposed to the 5% reported by the conventional-food consumers. Organic-food consumers in the focus group stated that the main reason they bought it was for their family's health although political, ecological, nutritional, and taste reasons were also mentioned. For these reasons as well as others, we feel that using price premiums paid for organic food as an estimate of consumers' willingness-to-pay for pesticide-free food may not be valid.

Total Diet Study

Unlike previous studies which have elicited information from subsamples of consumers or constructed proxies for pesticide awareness, this study will use the data in the FDA's Total Diet Study which attempts to measure actual pesticide ingestion by the American public. Foods were purchased from local supermarkets approximately 4 times each year throughout the U.S. Each market basket contained 234 food items that had been chosen, based on nationwide dietary surveys, to represent the diet of the U.S. population. Each of the 4 market baskets represented a different geographic region and is a composite of like foods collected in 3 cities in that region. The foods were purchased at the retail level and were fully prepared for consumption (peeled, cooked, etc.). They were then tested for the presence of pesticide residues and related compounds at FDA laboratories.

Day, Kuhn, and Vandeman used the Total Diet Study data to measure the 1970 creation of the EPA's impact on food safety risk. The pesticide data in the study was weighted by the level of risk subjectively assigned to each particular pesticide. They concluded that the creation of the EPA resulted in a decline of food safety risk of 53% and that this risk continued to decline reaching 91% at the limit.

Model Specification and Data

Capps and Schmitz provide a comprehensive review of models and techniques which have been used by agricultural economists to analyze health and nutrition issues. Among those reviewed include hedonic price and/or characteristics models which they state "are very attractive in analyses pertaining to nutrition issues." Furthermore, Kramer states that "in terms of overall importance of food safety, polls indicate that consumers consider it very important, generally on par with nutritional value, and even with, or a little less important than taste." The traditional hedonic price and characteristics models can easily be extended to incorporate the aspects of food safety. As far as we are aware, this theoretical model has yet to be applied to the issue of pesticides in food. Hence, this approach combined with the data from the Total Diet Study will be used to estimate consumers' willingness-to-pay for reduction of pesticides in fruits and vegetables. The hedonic price function is typically modelled by the following:

(1) $$P_{it} = \delta_i + \sum_j \beta_j x_{jit} + e_{it}$$

where P_{it} is the price of commodity i in period t, δ_i is the price of uniqueness of the i^{th} commodity, β_j is the marginal implicit price of the j^{th} nutrient and/or dietary component, x_{jit} is the amount of nutrient and/or dietary attribute j associated with commodity i in period t, and e_{it} is the disturbance term for the i^{th} commodity in period t. For each product consumed, the price paid by the consumer equals the sum of the marginal monetary values of the characteristics of the product. The marginal monetary value of each characteristic equals the quantity of the characteristic obtained from the marginal unit of the product consumed multiplied by the marginal implicit price of the characteristic. This basic model has been used in many empirical studies. Ladd (1982) and Capps and Schmitz provide excellent reviews of these.[1]

We used ten years of annual data from 1982 to 1991 because this was the time period in which the pesticide data from the Total Diet Study was available. Fifteen different fruits and vegetables listed in Table 1 were considered in this study. Hence, we had time series cross-sectional data. The annual prices per pound of these commodities were obtained from the Bureau

[1] Although Rosen as well as more recent authors have criticized hedonic price models for various reasons, Ladd (1991) has argued that they are still valid for food commodities which have characteristics or attributes which are exogenous to the consumer.

of Labor Statistics and adjusted to 1982-84 dollars using the Consumer Price Index for fresh fruits and vegetables. In terms of the right hand side variables in equation (1), twenty different nutritional characteristics were considered. The amounts of these nutritional characteristics per pound of each of the fifteen commodities were obtained from Composition of Foods: Raw, Processed, Prepared. These amounts are assumed to be constant over the ten years of this study.[2] The twenty nutritional characteristics and their units of measurement are listed in Table 2. As was the case for other researchers, we found it necessary to eliminate some of the nutritional characteristics from the estimation of the hedonic price function because of the high degree of correlation between some of the pairs of characteristics. The remaining nutrients considered in this study are denoted by an asterisk (*) in Table 2. Also, to conserve degrees of freedom, the prices of uniqueness for the fifteen different commodities were combined into just two prices of uniqueness -- one for fruits and one for vegetables. This approach is commonly taken by previous hedonic price studies (eg. Ladd and Suvannunt). In addition to the nutrient variables, a proxy for the pesticide attribute is also included as an explanatory variable. The pesticide attribute was obtained from the Total Diet Study data. First, for each of the fifteen fruits and vegetables, we simply summed the total amounts of pesticides that were contained in all samples collected during the calendar year. This, of course, suffers from the limitation that consumers are assumed to weigh the risk from each pesticide equally.[3] Then, the sums from each year were averaged by the number of samples collected in that year in order to reflect the average amount of pesticides detected in the commodity for the year. For example, the pesticide

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2 This is a reasonable assumption for fruits and vegetables but may not be reasonable for other commodities such as pork and beef which were not considered in this study.

3 As Day, Kuhn, and Vandeman point out, there are various databases available that contain toxicological information about pesticides. However, the formation of some type of index to weigh the relative risk of each pesticide is somewhat subjective, and toxicological information is not available for all the pesticides found in the Total Diet Study.

value for apples in 1982 represents the average sum of all pesticides, measured in parts per million (ppm), occurring in apples for the year. As is obvious, the amounts of pesticides varied by commodity and by year.[4]

Estimation and Empirical Results

Several error components estimation procedures were considered for the time series cross-sectional model in equation (1). Reported in Table 3 are the results of two of the models: a time-effect error components model, and an individual-effect error components model. As discussed in Judge et al., the two models account for random differences in intercepts for different time periods and different commodities, respectively. An error components model simultaneously considering both individual and time effects was also examined. However, the empirical results suggest that the individual effect is not significant at the 1% level when the time effect is also present. Insofar as the sign and magnitude of the estimated coefficients are concerned, the estimated models are surprisingly similar. However, the individual effect model has a significantly lower adjusted R^2, suggesting the importance of time effects.[5] Given the robustness of the results and the importance of the time effects, the implications of the estimated model are discussed below only for the time effect model in Table 3.

The implicit prices of the nutrients which we estimated were quite similar to results obtained in previous studies in both sign and magnitude. While neither the price of uniqueness of fruits or vegetables was significantly different from zero, the implicit price of fruit was estimated to be positive and vegetables was negative. Because the price of uniqueness is often interpreted as a proxy for taste, these results seemed quite

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4 Over the ten year period of this study, 101 different pesticides and related compounds were detected in the fifteen fruits and vegetables considered. The six most frequently occurring were: Endosufan II; Endosulfan Sulphate; Endosulfan I, Dicloran; DDE,P,P'; and Methamidophos.

5 The high explanatory power of the time effect term probably arises, in part, from the fact that all the explanatory variables except pesticide residues are time invariant.

intuitive. The implicit prices of water, food energy, and riboflavin were all positive and significant. Ladd and Suvannunt as well as Capps also found food energy and riboflavin to have significant positive implicit prices. We also found that the implicit price of calcium was positive and significant at the 6% level which was in agreement with Capps finding for this nutrient. Our results gave negative and significant implicit prices for fiber, ascorbic acid, thiamin, and sodium. Both Huffman and Capps found significant negative implicit prices for thiamin but significantly positive prices for ascorbic acid. In contrast, Ladd and Suvannunt also found a negatively significant implicit price of ascorbic acid. Hence, we can conclude that the implicit prices of the nutrients estimated in this study are quite reasonable and consistent in sign with previous work.

The Durbin-Watson statistics reported in Table 3 indicate that the estimated models are free from serious autocorrelation problems. However, one might argue that the conventional Durbin-Watson statistics are not appropriate for the models estimated here because of the inclusion of the cross-sectional data (in addition to time series observations). Hence, an alternative procedure for examining the extent of autocorrelation for each individual cross section was also explored. In particular, a first-order autocorrelation coefficient was estimated for each commodity, based on the time-series of the residues estimated from equation (1):

(2) $e_{i,t} = \alpha + \theta e_{i,t-1}$

for a given commodity i. The autocorrelation coefficient, θ, was not significantly different from zero at the 15% level for any of the fifteen commodities.

The most interesting aspect of this study was the statistically significant estimate of the implicit price of pesticide residues, \$ -.07995. It suggests that consumers would be willing to pay almost \$.08 per pound to reduce pesticides in their prepared fruits and vegetables by one part per million. Further interpretation is given by the additional information contained in Table 4. In the first column, the average amount of pesticides over the ten year time period is given for each of the fifteen commodities. It is interesting to note the wide disparity in the pesticide residues for the different commodities. Peaches, strawberries, baked potatoes, and cherries have the largest quantities of pesticides residues left on them after they are prepared for consumption while cabbage, carrots, lettuce, grapefruit, and tomatoes have the least. An estimate of the average willingness-to-pay per pound to eliminate pesticides in each of the commodities can be obtained by multiplying the implicit price of pesticides by the average pesticide level. These estimates are listed in the last column of Table 4 and can be compared to the average annual retail price of each commodity given in the second column. Our willingness-to-pay estimates are similar to the findings of Hammitt, Ott, Atkin, and Ott, Huang and Misra indicating that consumers are unwilling to pay much for pesticide-free produce. For example, we found that consumers would be willing to pay only about $.02 per pound to eliminate pesticides from apples which cost, on average, $.57. This is significantly lower than the $.375 per pound estimated by Van Ravenswaay and Hoehn (1991b). We also found that consumers would be willing to pay less than a penny per pound to eliminate pesticides from grapefruit in contrast to $.15 and $.19 (per grapefruit) estimated by Buzby, Skees, and Ready. However, for commodities with higher levels of detected pesticides, we found that consumers would be willing to pay more significant amounts. For example, consumers would be willing to pay 23% more for pesticide-free potatoes, 15% more for peaches, 8% more for strawberries, and 4% more for cherries. These estimates, however, are still much lower than the additional 85-90% more estimated by Eom.

Several explanations for the discrepancies in these findings could be entertained. Some of the studies try to estimate what consumers would be willing to pay to reduce or eliminate pesticides in one particular commodity as opposed to all produce or all foods, in general. Since it is less costly to eliminate pesticides in just one food, one might expect that consumers would be willing to pay more. To eliminate pesticides in more foods, you would expect that consumers would be willing to pay less per food item. Another possible explanation for our low estimates is that the Total Diet Study data gives information on actual pesticide content after the food is prepared or is "table ready." In other words, the produce is washed, peeled, etc. and then measured for pesticide residue. Presumably, this preparation reduces pesticide residues significantly so that consumers are willing to pay less to eliminate pesticides. One might also argue that hedonic price studies such as this one provide estimates of what consumers actually did pay for the various characteristics in a market-based situation. In this sense, our estimates are not as hypothetical as those based on survey or experimental results.

Conclusions and Suggestions for Further Study

The results of this study are consistent with the findings of other researchers in several ways. First, the hedonic price of pesticides was estimated to be both negative and significant and indicated that consumers were willing to pay nearly $.08 per pound to reduce pesticides in their prepared foods by one part per million. This is in agreement with other work which has shown that consumers are quite concerned about pesticide levels in the food supply and are willing to pay to reduce or eliminate this risk. However, our willingness-to-pay estimates are relatively small, ranging from 23% more for pesticide-free potatoes to virtually nothing for pesticide-free cabbage. This suggests that consumers accept the FDA's conclusions that the levels of pesticide residues in the food supply are quite safe; and given the small amounts of pesticides actually present in table ready foods, consumers are not willing to pay much to further reduce the pesticide residue levels.

There are several ways in which we would like to extend this study. Clearly, there are many more commodities which are included in the Total Diet Study that could be used to expand the data set used here. In addition, instead of simply summing over all pesticides found for a commodity, it may be better to use some type of risk index similar to that proposed by Day, Kuhn, and Vandeman to weigh the different risks incurred by the various pesticides. This, of course, would assume that consumers are aware of the various kinds of pesticides in their food and the amounts of these pesticides as well as being able to make accurate assessments about the health risk imposed by each pesticide.

Table 1. Fifteen Commodities

1. Apples
2. Oranges
3. Peaches
4. Pears
5. Strawberries
6. Grapes
7. Grapefruit
8. Cherries
9. Lettuce
10. Celery
11. Tomatoes
12. Cucumbers
13. Carrots
14. Cabbage
15. Baked Potatoes

Table 2. Nutritional and Dietary Attributes

Attribute	Unit of Measurement
1. Water*	%
2. Food Energy*	kcal.
3. Protein	g.
4. Carbohydrates	g.
5. Ash	g.
6. Calcium*	g.
7. Phosphorous	mg.
8. Iron	mg.
9. Sodium*	mg.
10. Potassium	mg.
11. Vitamin A value	I.U.
12. Thiamine*	mg.
13. Riboflavin*	mg.
14. Niacin	mg.
15. Ascorbic Acid*	mg.
16. Fiber*	g.
17. Cholesterol	g.
18. Saturated Fat	g.
19. Polyunsaturated Fat	g.
20. Monounsaturated Fat	g.
21. Pesticides*	ppm.

Table 3. Estimated Hedonic Price Equation[a]

	Time Effect Model	Individual Effect Model
Pesticide Residues	-0.07995 (-3.3)	-0.07327 (-2.7)
Uniqueness of Fruit	0.05331 (0.6)	0.05115 (0.5)
Uniqueness of Vegetables	-0.14880 (-1.3)	-0.15370 (-1.0)
Water	0.00184 (6.2)	0.00185 (4.7)
Energy	0.00084 (4.9)	0.00082 (3.7)
Riboflavin	3.01120 (13.2)	2.99226 (10.1)
Calcium	0.00087 (1.9)	0.00086 (1.4)
Fiber	-0.13401 (-12.8)	-0.13338 (-9.7)
Ascorbic Acid	-0.00150 (-7.3)	-0.00151 (-5.6)
Thiamin	-1.14456 (-5.7)	-1.12402 (-4.4)
Sodium	-0.00045 (-2.2)	-0.00044 (-1.7)
Adjusted R^2	0.84	0.76
Durbin-Watson	1.7	1.6
F Statistic [and p-value] on the Time Effect Term	4.9 [0.00]	
F Statistic [and p-value] on the Individual Effect Term		1.5 [0.13]

[a] Figures in parentheses are t ratios.

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