Modeling the Demand for Food Safety and the Implications for Regulation

E. Kwan Choi and Helen H. Jensen

Working Paper 90-WP 68
September 1990

Abstract

Modeling the Demand for Food Safety and the Implications for Regulation

E. Kwan Choi and Helen H. Jensen

The modern theory of demand which underlies much of economic analysis of consumer behavior is based on the premise that consumption goods are pure and do not involve risks. However, that is clearly not the case where concerns about food safety are involved. The awareness of linkages between consumption of foods and adverse health effects indicates the need for a new framework for investigating demand for food and food safety, and for guiding the appropriate government response to achieve optimal regulation of food safety levels. We develop such a framework and show that when safety is endogenous to the consumer's decision over a consumption bundle, perfect safety is not optimal. There are several implications of the model. Empirical analysis based on conventional demand theory may lack predictive power due to model misspecification and the unobserved survival probability function. Furthermore, if markets are perfectly competitive and consumers accurately informed about safety risk, there is no need for government regulation. However, when markets are not perfectly competitive, the answer is less clear-cut. And, risk differentiation may become a new basis for acquiring and exercising market power.

I. Introduction

Modern demand theory is based on the premise that consumption goods are pure and do not involve risks. However, that is clearly not the case in today's world where reports from the scientific community link exposure from pesticide residue to increased cancer risk, intake of toxins or pathogens to incidence of specific illness, and high levels of naturally occurring food components such as saturated food to increased risk of heart disease. The awareness of such linkages suggests that a new framework is needed to investigate demand for food and food safety, and to guide the appropriate government response to achieve a socially optimal level of food safety.

The news-breaking reports of hazards in a food appear to decrease the demand for the affected food. One example is the immediate decrease in fresh apple consumption in response to reports of alar residues in apples. While it is tempting to attribute these shifts in demand to changes in tastes or preferences, modern demand theory is based on the assumption that consumption bundles are ranked by ordinal preferences and is incapable of analyzing consumer choices under risk. This paper attempts to answer questions on consumer response to food safety concerns by combining traditional demand theory and von Neumann-Morgenstern expected utility theory. The framework developed provides a basis for constructing and interpreting empirical analyses and making public policies on food safety more effective.

The purpose of this paper is twofold. First, we investigate demand for a risky consumption good and food safety. Since demand for safety cannot be derived from the conventional ordinal utility analysis, expected utility analysis is employed to derive the demands for "quantity" and "safety." The hazard in the risky good, food, is assumed to decrease the probability of survival. When safety is endogenous to the consumer's decision over a consumption bundle, we find that perfect safety is not optimal. Second, we consider plausible market organizations that may develop with or without government intervention and evaluate the implications of risk in food on approaches to regulation. We show that there is no need for government intervention to induce a socially optimal level of food safety if the market is perfectly competitive and consumers are accurately informed. The appropriate role of the government in this case is to verify producer claims on hazard content - not to regulate the level of food safety. When markets are not perfectly competitive, the answer is less clear-cut.

The organization of this paper is as follows. First, we review the role of risk in the development of demand theory. Second, we consider the case where the hazard content of the risky good is assumed to be fixed. We derive the demand for a risky consumption good. In addition to the usual price and income variables, the impurity content of the risky good (or other measures of hazard) is shown to be an important determinant of demand for the risky good. Next, we examine the case where the consumer chooses not only the quantity of the risky good but also the level of hazard in the risky good. In this case, demands for food safety and quantity are jointly derived. The final section addresses implications for government regulation of food safety.

II. Risk and Demand

Two hundred years ago Jeremy Bentham (1789) - who laid the foundation of utility analysis - singled out certainty or uncertainty as a major factor in assessing the utility of a commodity. Specifically, Bentham argued that "the pleasure or pain considered by itself, will be greater or less, according to its (i) intensity, (ii) duration, (iii) certainty or uncertainty, and (iv) propinquity or remoteness." Two other factors Bentham included for assessing the pleasure or pain from a consumption good are also caused by uncertainty: *fecundity* refers to the chance that the activity is followed by the same kind of pleasures or pains, while *purity* is the chance that the activity is not followed by sensations of the opposite kind. Economists have considered aspects of risk in consumption for some time. However, incorporating risk considerations in demand theory has not been a major concern to economists. Consequently, we still lack clear guidance from theory on how to incorporate uncertainty in the quality of goods in the theory of demand.

Modern demand theory is based on the premise that consumption goods are pure or riskless. In 1892 Irving Fisher argued that there is no need to introduce cardinal utility to derive demand curves because the total utility function cannot in general be deduced from indifference curves. However, demand for risky consumption goods can only be derived from expected utility theory based on cardinal preferences. Bentham's early work on utility theory clearly indicates that risk is a major factor that should be taken into account when assessing (expected) utility from consuming "impure" or risky consumption goods.

Risky consumption goods should be distinguished from the riskless or "pure" consumption goods in conventional demand theory. Pure consumption goods yield demand curves which can be derived from the conventional indifference curve analysis. In contrast, risky consumption goods not only yield positive utility directly, but also have adverse side effects on the health or life expectancy. The consumer has to weigh the direct utility benefits and health risks of the risky consumption good. Accordingly, a von Neumann-Morgenstern utility function is employed to derive demand curves.

This paper differs in two important respects from other contributions in the literature which allow quality differences. First, because food safety is an instance of the consumption decision made under uncertainty, demands for risky and riskless goods are derived from an expected utility analysis, rather than from the conventional ordinal utility analysis. Second, unlike quality characteristics which are discernible to the consumer upon inspection (e.g. Bockstael, Hanemann), the hazard levels in food are not discernible by visual inspection and do not generally have immediate side effects after consumption. Thus, the consumer is assumed here to be unable to discriminate among foods with different levels of hazard by visual inspection. Indeed, this is one of the more challenging problems of food safety policy.

III. Demand for Food When There is Fixed Hazard

The traditional models of demand consider only "pure" goods whose demands can be derived from ordinal preferences. In contrast, we assume that the food contains a hazard such as a toxin or pathogen. The hazard is embodied in the risky good and cannot economically be separated by the consumer. We begin with the case where the level of hazard in food is exogenous and cannot be controlled by the consumer. This does not mean that the consumer is not concerned with food safety but that he or she cannot choose different levels of food safety in selecting the bundle of consumption goods. The selection is only over different levels of the risky good.

For simplicity, we assume that all firms are identical and produce a homogeneous risky good X. The toxin is tasteless and cannot be detected during consumption and hence does not affect utility in the current period. The absorbed toxin, however, affects the "health" of the consumer in the next period. Although the hazard is undetectable during consumption, we assume that it can be measured objectively and that the consumer is informed about its hazard content. Note, we are not addressing the issue of information here.

Extensions of the Demand Model

We consider an individual who lives for two periods with time-invariant utility functions over two goods: a risky food X and another (numeraire) good Z, which is a composite good including all nonfood commodities with price of unity. The probability of survival is assumed to be less than one and the consumer faces uncertainty regarding survival into the next period. Note that the term "survival" is used in a broad sense. Survival could be interpreted as the state of good health and nonsurvival the state of poor health. While survival is uncertain, the probability of survival is known and deterministically linked to the quantity of the risky food consumed. Specifically, the consumer is assumed to know the probability of survival which is affected by the quantity of the risky commodity consumed.

If the individual survives into the next period, his preferences in each period can be represented by a monotone increasing and concave von Neumann-Morgenstern utility function

$$u_i = u(X_i, Z_i)$$

where X_i and Z_i are the quantities of the risky good and the riskless composite good consumed in period i, respectively. The budget constraint in each period is given by

$$p_i X_i + Z_i = I_i, \quad i = 1,2,$$

where p_i is the price of the risky good in period i, and the price of the composite good is unity in both periods.

Let π be the probability of survival, $0 \leq \pi < 1$. If the individual survives, the consumer maximizes $u(X_2, Z_2)$ subject to the budget constraint in the second period. Let $X(p_2, I_2)$ and $Z(p_2, I_2)$ denote the second period demand functions. The indirect utility in the second period is,

$$v(p_2, I_2) = u[X(p_2, I_2), Z(p_2, I_2)].$$

If the individual does not survive, he receives no income. Without loss of generality, it can be assumed that the utility level in the second period is zero if the individual fails to survive ($u_2 = 0$). Assume further that the utility function in each period is normalized so that the utility in the second period when the individual survives is unity, i.e., $v = 1$. Then the second period utility can be written as a random variable,

$$u_2 = \begin{cases} 0, & \text{with probability } (1 - \pi), \\ 1, & \text{with probability } \pi. \end{cases}$$

The expected utility of the consumer for both periods is

$$J = u(X, Z) + \pi\delta, \qquad (1)$$

where δ is a discount factor, $0 < \delta \leq 1$.

Now, let α denote the amount of impurity per unit of the risky good X consumed. Then the total amount of impurity absorbed, C, is

$$C = \alpha X. \tag{2}$$

For simplicity, the hazard content is normalized so that $0 \leq \alpha \leq 1$. Then $\beta \equiv 1 - \alpha$ is a measure of safety because an increase in β indicates increased safety. The probability of survival is assumed to be a function of the impurity absorbed:

$$\pi = \pi[(1-\beta)X], \tag{3}$$

This survival probability function captures Bentham's notion of the risk or impurity in the consumption good, and is assumed to have the properties that $\pi'(C) < 0$ for $C > 0$ and $\pi'(0) = 0$. That is, the known probability of survival reaches its maximum at $C = 0$ when there is no impurity, and decreases as the amount of impurity absorbed through the risky good increases.

The specification of the survival probability function is important to the determination of the optimal amount of the risky good X consumed. If the survival probability function is strictly concave in the hazard ($\pi'' < 0$), then the probability of survival increases at a decreasing rate as β increases. On the other hand, if $\pi(C)$ is convex in C, then the probability of survival increases at an increasing rate as β increases. Since the individual lives only two periods, the probability of survival becomes a determinant of demand for the risky good in the first period, but not in the terminal period.

To facilitate the analysis in the next section we substitute $Z = I - pX$ in the utility function. The objective function (1) can be rewritten

$$J = u(X, I - pX) + \delta\pi[(1-\beta)X]. \quad (4)$$

Assume that the price of the risky good p is not prohibitive so that the expected utility in (4) is increasing in X at X = 0.[1] The first order condition for an interior solution (X > 0) is

$$J_X = u_X - pu_Z + \pi'(C)(1-\beta)\delta = 0. \quad (5)$$

Solving (5) yields the demand functions,

$$X = X(p, I; \beta, \delta), \qquad Z = Z(p, I; \beta, \delta). \quad (6)$$

This result implies that when the level of hazard is fixed demand functions are affected by food safety, as well as by prices and income.[2]

Food Safety and the Demand for the Risky Food

We now investigate the effect of a change in hazard content on the demand for the risky good. An increase in food safety or a decrease in hazard content will increase the probability of survival. Since the consumer cannot differentiate goods with different levels of hazard by visual inspection, products are assumed to carry labels with hazard content to enable an informed consumption decision. We assume that the consumer is fully informed about the hazard content, i.e., product labels are truthful, false labeling and advertising are ruled out, and the consumer understands the information being conveyed (National Research Council 1989).

How does a decrease in the level of hazard α affect the demand for the risky good? Differentiating (5) with respect to β gives

$$\partial X/\partial\beta = - J_{X\beta}/J_{XX}$$

where J_{XX} is negative by the second order condition, and

$$J_{X\beta} = -\delta\cdot(\pi' + (1-\beta)X\pi''). \tag{7}$$

If the probability function is concave ($\pi'' < 0$), then $\partial X/\partial\beta > 0$. In this case, increased safety increases demand for X. However, the sign of $\partial X/\partial\beta$ is indeterminate if $\pi'' > 0$.

How does the probability of survival change in response to an increase in impurity content α? This is a relevant question for public regulators. Differentiating $\pi(\alpha X)$ with respect to α gives

$$\partial\pi/\partial\alpha = \pi'(X + \alpha(\partial X/\partial\alpha)) = \pi' X(1 - \theta), \tag{8}$$

where $\theta \equiv -(\partial X/\partial\alpha)(\alpha/X)$ is the risk elasticity of demand for X. The total amount of impurity absorbed, αX, increases, remains constant or decreases according to whether the risk elasticity of demand for X is less than, equal to, or greater than unity. For example, if the demand for X is risk inelastic ($\theta < 1$), then an increase in the impurity content of X increases the total amount of impurity absorbed αX and hence reduces the probability of survival. On the other hand, if demand for X is risk elastic ($\theta > 1$), an increase in α reduces the total impurity absorbed and increases the probability of survival. Note that θ represents the consumer's ranking of safety for product X and may differ among products.

IV. Demand for Food Safety

In the preceding section we considered demand for food when riskiness of food is exogenous and food safety could not be controlled by the consumer. In this section we relax this assumption and derive demand for food safety. It is important to note that food safety is not an independent good, separate from the demand for food. Thus, we investigate how demand for food safety and demand for quantity are jointly determined in the consumption decision. We assume that the price of food $p(\alpha)$ consumers have to pay depends on how risky the consumption good is. This is the case since, in general, it is costly to increase food safety for given quantity of food, and hence the total price the consumer pays also depends on food safety.

Let $p(\beta)$ be the price of X with impurity level $\alpha = 1 - \beta$. In general, removal of an impurity from food raises production costs, and thus $p(\beta)$ is assumed to increase as β increases. For simplicity, we assume a linear price schedule, $p(\beta) = p^{\circ} + q\beta$, where q is the price of safety, i.e., the price the consumer has to pay to eliminate impurity. The budget constraint is: $I - (p^{\circ} + q\beta)X - Z = 0$.

The consumer's problem is to choose X and β to maximize utility

$$J = u[X, I - (p^{\circ} + q\beta)X] + \delta\pi(\alpha X). \tag{9}$$

The first order conditions for maximum utility are

$$J_X = u_X - (p^{\circ} + q\beta)u_Z + \alpha\delta\pi'(C) = 0. \tag{10a}$$

$$J_{\beta} = - X(qu_Z + \delta\pi') = 0. \tag{10b}$$

Thus, demands for X and safety β can be written

$$X = X(p^{\circ}, q, \delta, I), \qquad \beta = \alpha(p^{\circ}, q, \delta, I).$$

Demands for X and β now depend on the prices of "quantity" and "safety", as well as income and the discount factor δ. Note also that the perfect safety situation ($\beta = 1$) is a corner solution. Under suitable conditions an interior solution to (10a) and (10b) exists. Thus, in general the optimal safety level β is positive and less than unity for all p^o. It can also be shown that an increase in p or q has an ambiguous effect on demands for X and β.

Quantity versus Safety Choice

In order to evaluate the consumer's tradeoff between quantity and safety when safety is endogenous, we consider the effects of changing own prices on demands. A change in the price of quantity or safety affects the amount of money allocated to the numeraire good, and this response of the numeraire good obscures many comparative static results. Specifically, a change in a parameter not only affects demands for X and β for a given budget allocated to the risky consumption good, but also affects them indirectly through an adjustment in the total expenditure on the risky good. Thus, the total effect is the sum of the direct effect and the indirect effect through the adjustment in the budget allocated for the risky good.

Algebraically, the slopes of demand curves are given by

$$\partial X/\partial p^o = (\partial X/\partial p^o)|_B + (\partial X/\partial B)(dB/dp^o), \tag{11a}$$

$$\partial \beta/\partial q = (\partial \beta/\partial q)|_B + (\partial \beta/\partial B)(dB/dq), \tag{11b}$$

where B is the budget allocated to be spent on the risky good X. In (11a) and (11b) the first terms are direct effects and the second terms are the budget effects. If X and β are normal goods, then $\partial X/\partial B > 0$ and $\partial \beta/\partial B > 0$.

The choice problem can thus be decomposed into two stages. In the second stage we consider how changes in the prices of the risky good, p^o, and of food safety, q, affect the choice of quantity and safety. The second stage ignores the budget effect of changes in the prices of quantity and safety. This restriction allows us to focus sharply on the direct effects of changes in the prices on the demands for quantity and safety.

In the first stage, income is allocated between B and Z, and the expenditure is subject to the budget constraint, B + Z = I. As shown in (11a) and (11b), a change in p^o or q has indirect effects on X and β via the change in the budget allocation B to the risky good. Unlike in the conventional demand theory, the budget curve is convex to the origin. Thus, it is quite possible for safety to be a Giffen good. An increase in q *could* lead to an increase in the level of safety demanded. Alternatively, for a given price of safety, a decrease in the quantity price, p^o, could decrease the amount of X consumed. Thus, economists need not be alarmed if estimated demand systems reveal that food safety is a Giffen good.

V. Implications for Regulation of Food Safety

When the food industry produces a potentially hazardous food, the government may regulate its activity in three directions. First, the government may regulate how information about risk characteristics of products are produced and disseminated to consumers. Second, it can regulate the industry output directly in order to reduce hazards to the public. Third, it can regulate the level of food safety.

Regulation of Information

On the supply side, resources are used up in reducing the hazard content or in increasing food safety. Information about the hazard content is also costly to produce, and to disseminate to consumers. Thus, it is necessary to consider aspects of the market and market structure in order to evaluate the implications of risk and hazard on the demand for food, and on the socially optimal level of hazard. There are many firms in the food processing industry. Although a monopoly structure is not likely to emerge, some degree of market power may exist, for example, due to advertising or the technology of processing (Connor et al. 1985).

Monopolistic competition or differentiated oligopoly could develop in the food processing industry in part because producers can differentiate their products in terms of hazard content or health improving characteristics. In the traditional theory of monopolistic competition, firms differentiate their products in terms of easily identifiable characteristics, such as color, weight, horsepower, etc. Consumers can easily discriminate these different products by visual inspection. In contrast, if the firms in the food processing industry differentiate products by risk or hazard content, and the level of hazard is not verifiable by visual inspection, producers must provide information about the hazard level in order to differentiate effectively. Accurate information about risk characteristics of products is also necessary for optimal consumption decisions.

The need for information on hazard content, however, poses a regulation problem. In the absence of government intervention, producers have no incentive to report the hazard content truthfully since that may depress demand for their products. This problem can be resolved if a producer group voluntarily organizes or uses an existing marketing board or producer union to monitor the hazard content of their products. The objective would be to increase demand for the hazardous good by encouraging consumers to discriminate the producer group's products from those of nonparticipating producers with potentially higher levels of hazard. Even in this case, the producer group may be unlikely to reveal information about hazards common to all products in the industry because such negative information would depress the demand for the industry products.

A consumer group could also monitor product testing to protect consumers by providing more accurate product information. However, it is difficult to organize consumer groups. A more practical solution is government regulation of the information. With enough resources, the government could either directly test products and collect and disseminate information about risk characteristics, or induce producers to disseminate accurate information by random sampling or testing.

The role of government may not be limited to insuring that producers provide consumers with accurate information about hazard content. It may also be necessary to regulate how products are differentiated by risks. Even if each producer provides a product label indicating the correct hazard content, each producer may choose a different level of risk. With this approach, however, infinite product differentiation by risks raises the cost of processing information to consumers. Grading (treatment with pesticide, product inspection, etc.) or product standardization would reduce the cost of processing information. For many products, only a few levels of hazard could be chosen for practical reasons; if consumers are diverse in their tastes, several levels of food safety could be specified, depending on whether consumer groups could be easily separated by their socioeconomic characteristics. For instance, only two categories such as low salt and regular products, or diet and regular beverage, etc. may be allowed. The government may specify a maximum allowable hazard level within a regulated category. If the government regulates the hazard content by allowing only a few categories, it becomes difficult for producers to differentiate their products by risks. In this case, producers might be forced to behave as competitive firms. Producers may remain monopolistically competitive or oligopolistic if they can compete by other means.

Regulation of Quantity and Safety

If the government regulates producers to disseminate accurate information about risk characteristics of products, will producers supply the socially optimal levels of food quantity and safety? Or is there a need for the government to regulate the optimal levels of quantity or safety? For simplicity, we consider optimal level of safety for the representative consumer in a well defined consumer group. All producers are assumed to be identical. Consider a representative firm producing a "hazardous" product. The firm's profit is

$$\pi = (p^{o} + q\beta)X - C(X,\beta). \qquad (12)$$

The first order conditions are

$$\partial\pi/\partial X = (p^{o} + q\beta) - C_X = 0. \qquad (13a)$$

$$\partial\pi/\partial\beta = qX - C_\beta = 0. \qquad (13b)$$

In the absence of government intervention, the intersection of the supply and demand curves determine the optimal level of safety. The socially optimal level of hazard, which is not necessarily zero, is obtained by solving the utility maximization problem of a representative consumer who also receives profit from production. That is, if the consumer is also a producer, he will choose the optimal levels of output and hazard. Policy makers can utilize this information to set the socially optimal food safety standard.

If the representative consumer were to produce the risky good and safety himself, he would choose the levels of X and β where marginal benefits are equal to marginal costs. Equations (13a) and (13b) indicate that the representative consumer would produce the same levels of X and β as produced by competitive firms. This is because the consumer equates the marginal benefit of each good to its price and the competitive firm equates marginal cost to the price. This condition holds for both the tangible good X and the intangible good β called safety. Thus, when the supply and demand for each good clears, the marginal benefit is also equal to marginal cost.

The Structure of Market and Regulation

The above reasoning implies that there is no need for the government to regulate the level of safety. The desired level of safety the policy maker chooses is exactly the level chosen by producers and consumers. Insofar as the product labels deliver accurate information in language transparent to consumers, there is no need for active government intervention. *The role of government should be limited to verifying the producer claims about the hazard content, and not on the levels of food safety or output when the market is perfectly competitive.* Regulation of the levels of food safety below or above the free market level would result in a welfare loss.[3]

This result also holds when there are many consumer groups which choose different levels of food safety; each consumer group and the corresponding producer group will jointly choose an optimal level of food safety in each product category. If products are supplied by a differentiated oligopoly, a case can be made for government regulation of both quantity and safety. However, when the market is imperfectly competitive, partial regulation of output will guarantee neither the optimal level of food safety nor the optimal level of the quantity of the risky good.

Since it is costly to lower the toxin level and consumers have difficulty discriminating products with different levels of hazard, a perfectly competitive firm has no incentive to reduce the toxin level. Monopolistically competitive food suppliers could differentiate the toxin levels in food, but consumers bear the high information cost of search or advertisement to find goods with the "desired" toxin level. Consumers are not likely to bear high information cost when there is a monopolistic food supplier. However, there is no incentive for the monopolist to produce either the level of output or of hazard which is socially optimal.

In sum, what are the implications of having "hazard" in a food from the perspective of the market and for regulation? In the absence of government intervention, perfectly competitive firms do not have an incentive to provide safe products if there is a cost involved in reducing the hazard and if consumers cannot discern the hazard. If consumers are able to discern the hazard or if consumers are perfectly informed, there is no need for government regulation. Thus, when the market is perfectly competitive, the primary role for the government or a marketing group would be to verify the accuracy of the information provided.

If the market is not competitive and firms engage in product differentiation by other means, then the market solution will not generally be optimal. In an imperfectly competitive market, output occurs at a point where price exceeds marginal cost. Thus, if the food processing industry producing a potentially hazardous good is not competitive, the industry output will not be socially optimal. Moreover, willingness to pay for safety may also exceed marginal cost of safety. In this case, it may be necessary for the government to regulate both quantity and safety levels. Regulating only the quantity on the supply side will not generally guarantee the optimal level of food safety.

VI. Concluding Remarks

Modern demand theory is based on the premise that consumption goods are pure and do not involve risks. In this paper we investigate demand for risky goods. The risky good increases utility in the current period, but hazard in the risky good decreases the probability of survival for the consumer. Since individuals cannot detect the hazard themselves, the information on the hazard content is disseminated by producers. A von Neumann-Morgenstern utility function is used to derive demand functions for the quantity and the safety level. We have argued that there is no need for government regulation to achieve a socially optimal level of food safety if the market is perfectly competitive. Government efforts may be best directed to verification and communication of hazard information to consumers so that they can make well informed consumption decisions.

The challenges and problems implied for empirical research and for appropriate government response are many. Although our list is not exhaustive, we would like to highlight a few. First, the implication for demand theory when the risks of consumption are taken into account is that the probability of survival - which represents the individual's physiological response to the hazard - affects the usual price and income elasticities for demand for the risky consumption good X. As such, traditional demand parameters are not sufficient to capture consumer response to changes in risks. For some hazards, the "bias" may be quite large.

A major problem for empirical analysis of demand when there is risk is the lack of predictive power of conventional demand theory. Estimated demand equations using price and income as explanatory variables are misspecified. This may be particularly true when demand for safety is endogenously determined. Moreover, economists need not be alarmed even if estimated demand equations reveal that quantity or safety is a Giffen good. Validating the consumer demand under these circumstances requires significant knowledge about the properties of the survival probability function. For example, imposing restrictions such as adding up and homogeneity on estimated equations will require extreme caution since demand functions are not derived from ordinal preferences.

We have assumed that information can be provided to consumers directly. Insight about risk communication (National Research Council 1989) indicates that this may not be the case. A consumer may have a subjective belief about the hazard content of the risky good. Even if accurate information about the hazard is transmitted, the consumer belief may be sticky and slow to adjust to new transmissions. Thus, results of empirical demand studies need to be conditioned on how accurately consumers receive information and how fast they revise their subjective beliefs. While not underestimating the difficulty of information transmission, we have tried to identify issues directly related to the "modern demand theory," as it is no longer capable of analyzing demands for risky consumption goods.

Finally, we argue that market structure and firm behavior become important considerations of government response to food safety issues. Although we have shown that government regulation on the level of food safety is redundant when the markets are competitive, government response would be different when products are differentiated or firms hold some degree of market power. In general, both heterogeneous oligopoly and monopolistic competition are market structures which exist in the food industry (Connor et al. 1985). For relatively unprocessed agricultural commodities (meat, eggs, fresh fruits and vegetables) we may be safe in applying the model of perfect competition. For other food products, such as processed products, public policy will need to address the issues of regulating firms which engage in risk differentiation (product differentiation by risk or safety) because it is a new basis for acquiring and exercising market power.

Endnotes

1. This assumption is made because even if there is risk an individual has to consume some amount of food to survive into the second period.

2. The general expression of the expected utility is $u(X_1,Z_1) + \delta[\pi u(X_2,Z_2) + (1-\pi)u(0,0)]$. Since the total utility is a weighted sum of von Neumann-Morgenstern utility functions, a positive linear transformation $\psi(\cdot) = au + b$, $a > 0$, of both $u(X_1,Z_1)$ and $u(X_2,Z_2)$, will affect the demand for the risky good. However, for a given π, a monotonic transformation of $J(X_1,Z_1,X_2,Z_2) = u(X_1,Z_1) + \delta\pi u(X_2,Z_2)$ does not distort the marginal rate of substitution between current and future consumption goods, and hence does not affect the demand for the risky good. To see this, let $\phi = \phi(J)$, with $\phi' > 0$. The first order condition reduces to $\phi'(J)J_X = 0$, or $J_X = 0$. However, a change in the probability of survival affects the intertemporal marginal rate of substitution.

3. In a different context Bockstael also argues that minimum quality standards lead to social losses.

REFERENCES

Bentham, J. 1789. An Introduction to the Principles of Morals and Legislation, Chapters I-IV. London: T. Payne & Son. 1968. Reprinted in A. N. Page (ed), Utility Theory: A Book of Readings. New York: John Wiley & Sons.

Bockstael, N. E. 1984. The Welfare Implications of Minimum Quality Standards. American Journal of Agricultural Economics 66: 466-471.

Connor, John M., Richard T. Rogers, Bruce W. Marion, and Willard F. Mueller. 1985. Food Manufacturing Industries. Lexington: D.C. Heath and Company.

Fisher, I. 1892. Mathematical Investigations in the Theory of Value and Prices. New Haven: Connecticut Academy of Arts and Sciences. 1961. Reprinted, New York: Augustus M. Kelley.

Hanemann, W. M. 1980. Quality and Demand Analysis. New Directions in Econometric Modeling and Forecasting in U.S. Agriculture, ed. G. C. Rausser. New York: Elsevier/North-Holland Publishing Co.

National Research Council, Committee on Risk Perception and Communication. 1989. Improving Risk Communication. Washington, D.C.: National Academy Press.

von Neumann, J. and O. Morgenstern. 1953. The Theory of Games and Economic Behavior, Chapter I, Section 3, 15-31. Princeton University Press, Third Edition.