Policy Implications for U.S. Agriculture of Changes in Demand for Food

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Social Opportunity Costs of Food-borne Disease

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According to the Harrington and Portney (1987) model, the social opportunity costs of health hazards are made up of three elements: the cost of illness, defensive expenditures to reduce the health threat, and the disutility resulting from illness. For microbial food-borne disease, consumer cost-of-illness estimates conservatively range from \$3.7 to \$11.4 billion. Defensive expenditures by consumers and the disutility of illness have not been estimated. Expenditures by industry and the government have not been thoroughly examined, but evidence suggests that they are in the hundreds of millions of dollars annually.

Food risks have been increasingly in the news—Alar in apples, cyanide in Chilean grapes, *Escheriohia col.* 0157:hg in hamburger, and *Salmonella* in chickens and milk (about 200,000 people in the Illinois area contracted salmonellosis from milk in 1985). Economists are interested in determining whether food safety concerns reflect mass hysteria, or whether a substantial share of society's resources are indeed being consumed by food-borne disease. Examining the damages associated with the current level of health risk and estimating current levels of economic costs has historically been called the cost-of-illness method. These estimates can be used in benefit-cost analyses comparing regulatory options for food-borne disease control.

Economists have been developing new methods, such as the willingness-to-pay method reported by Shin et al. (1991), for estimating social welfare improvements associated with reducing health risks. Another method is the examination of the costs of defensive actions taken by individuals to reduce their risks. Harrington and Portney (1987) have modeled cost-of-illness estimates and costs of defensive actions and compared the results with willingness-to-pay estimates. They use a static model of constrained utility maximization, in which sickness reduces work or leisure time, induces remedial medical expenditures, and causes disutility. All sicknesses are assumed to be equally intense. Individuals can take defensive actions to reduce their chances of sickness. Sickness is a function of food-borne health hazards[2] and defensive expenditures:

Sickness = S(Hazard, Defensive expenditures)

At the margin, a dollar's worth of defensive expenditure consists of three parts: the dollar value of disutility arising from additional sick time, the

[1]The views presented in this paper do not reflect official policy of the United States Department of Agriculture. The author expresses appreciation to J. William Levedahl and Michael Weiss for comments and suggestions.

[2]Harrington and Portney (1987) use the symbol P because they are modeling the effects of pollution. Since food hazards are discussed here the symbol has been changed to H.

opportunity cost of sickness valued at the wage rate, and the out-of-pocket expenses caused by increased sickness.

Defensive expenditures are typically omitted from cross-sectional epidemiological studies. Since some individuals do take such measures to mitigate or prevent the effects of the food-borne hazard, what is actually observed is an underestimate of the effect of food-borne hazards on health. For food-borne disease, these defensive measures include washing dishes, cooking food, using refrigeration, hiring people to clean the kitchen and launder kitchen towels, peeling fruits and vegetables, etc.[3] Some of these defensive actions are joint products and have other benefits, such as the aesthetic value of a clean, uncluttered kitchen and the benefit of reducing kitchen odors.

By omitting the impact of defensive actions and expenditures, epidemiological studies omit the first of the right-hand side terms in the following equation from the estimates of the marginal effect of changes in the food-borne hazard on observed sickness levels:

$$dS/dH = S_D D_H + S_H$$

Where S = sickness, H = food-borne disease hazard, and D = defensive expenditures. The estimates typically of cost of food-borne disease only include the medical costs and productivity losses associated with actual sickness and ignore the reduction in "potential" sickness caused by defensive expenditures.

In the Harrington and Portney (1987) model, individuals' true willingness to pay to avoid an increase in food-borne health hazards is the amount resulting from the cost-of-illness approach (lost wages or leisure time due to food-borne illness and the resulting out-of-pocket medical expenditures) plus the dollar value of the disutility associated with the food-borne illness and the change in defensive expenditures associated with the increase in a food-borne hazard.

For cancer-causing chemicals and pathogens in food, a minimum dose is not required to cause disease: one exposure to chemicals or one pathogen finding the "right" location in a human body can cause disease. There is no threshold. Rather, increased exposure to a foodborne hazard increases the probability of illness and shifts the distribution of illness severity to more serious disease outcomes (i.e., $dS/dH > 0$). As shown in the upper right-hand quadrant in Figure 1, there can be either a linear relationship between exposure and illness (constant marginal risk), an increasing probability of disease (increasing marginal risk) or decreasing marginal probability of disease (decreasing marginal risk). While we do not know specifically which chemicals and pathogens have which of the relationships illustrated (or combinations thereof), it is highly unlikely that increasing exposure to a hazard will **reduce** illness as shown in the lower right-hand quadrant (Figure 1). As a consequence, Harrington and Portney (1987) conclude that:

- $dS/dH > 0$,

- the marginal willingness to pay exceeds the sum of changes in defensive expenditures and the cost of illness, and

- a cost-of-illness estimate can be used as a lower bound estimate of the true benefits until more information is available on defensive expenditures by individuals (p. 112). The rest of this paper surveys the literature on social opportunity cost estimates for the current level of food-borne disease in the United States.

Food-borne Disease Cost Estimates

Three groups affect the amount of foodborne disease by their food production and food preparation actions: consumers, industry, and the public health

[3]The model could be extended to differentiate between actions taken for the purpose of reducing risks and those actions that actually have the effect of reducing food risks.

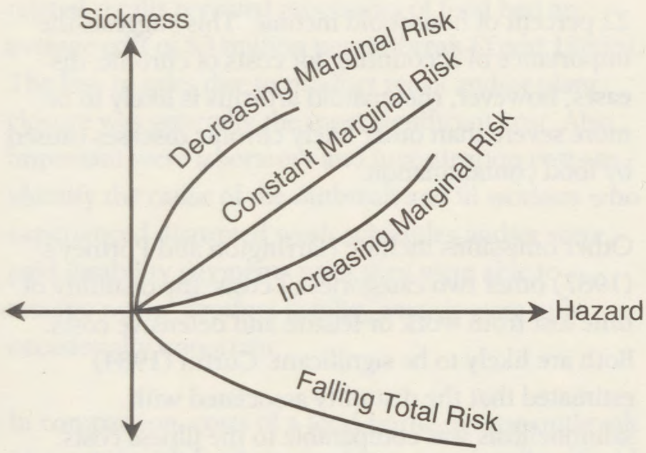

Figure 1. Quantity and severity of sickness as a function of exposure to foodborne hazards

sector of government. All three groups bear the costs of defensive actions to reduce food-borne disease as well as direct costs imposed by a food-borne disease outbreak.

For pesticide residues on food, a worst-case EPA estimate is that these residues result in up to 6,000 cases of cancer annually in the United States (U.S. Environmental Protection Agency 1987). A 1990 EPA report (U.S. Environmental Protection Agency 1990) estimates a "moderate" risk. However, no one has estimated the human illness costs of these cases of cancer and thus the social opportunity costs of pesticide health risks are not discussed here. For microbial food-borne diseases, some partial cost estimates are in the literature and the rest of this paper examines these.

Consumer Costs

Using detailed estimates of medical costs and productivity losses for salmonellosis (Roberts 1987) and listeriosis (Roberts and Pinner 1990), Roberts (1989) estimated the average cost of illnesses from other food-borne bacterial pathogens. Total medical costs and productivity losses were estimated at $3.5 to $4.8 billion annually for the food-borne bacterial diseases and based on earlier estimates of deaths and illnesses from the food-borne bacterial diseases estimated by Bennett et al. (1987). The bacterial pathogens with the highest total estimated costs were *Campylobacter*, *Salmonella*, and *Staphylococcus*, each of which has costs of around $1 billion annually. A second cluster of pathogens had estimated costs of around $200 million annually—*Listeria*, *Streptococcus*, and *Vibrio*.

Epidemiologists and medical doctors have also made cost estimates. For example, Garthright, Archer, and Kvenberg (1988) estimate that infectious intestinal illnesses related to food afflict about 33 million people annually, with associated annual costs of $7.7 billion. However, the costs of deaths are omitted from the estimates.

Other studies by epidemiologists have estimated costs for an isolated outbreak of food-borne bacterial infection [e.g., Shandera et al. (1985)]. Since bacterial food-borne diseases typically run the gamut from causing mild to severe illness, it is difficult to know whether the estimates reflect the average, mild, or more severe cases. It may be the more severe cases that are most likely to be noticed by the medical community.

Roberts (1985) has also estimated the costs for three parasites: beef tapeworm, trichinosis, and congenital toxoplasmosis. Estimated costs for tapeworm and trichinosis are minor; beef tapeworm causes human illness costs of around $100,000 annually and trichinosis causes losses of $1.5 to $2.2 million annually (Roberts 1985). Roberts and Frenkel (1990) estimated costs for congenital toxoplasmosis associated with a hog parasite, *Toxoplasma gondii*. Expert opinion suggests that pork is responsible for 50 to 75 percent of U.S. cases (Roberts 1985), or costs of $0.2 to $6.6 billion annually (Table 1). The wide range in the estimates is due to the great uncertainty in the number of fetal infections annually in the United States.

Table 1. Social costs of congenital toxoplasmosis

Cost category	Low estimate	High estimate
	Million $	
Productivity Loss	250	5,840
Special Education/ Residential Care	116	2,834
Medical Costs	3	82
Total	368	8,756

SOURCE: Roberts and Frenkel (1990), Roberts (1985).

Summing these cost-of-illness estimates results in a total estimate of medical costs and productivity losses for bacteria and parasites of $3.7 to $11.4 billion annually in the United States.

Omitted from the cost-of-illness estimates are food-borne viruses, which some epidemiologists believe to be as important a cause of food-borne illness as bacteria; however, we do not have concrete estimates of the number of cases yet. Also omitted from the cost estimates because of lack of data are cases of human illnesses caused by fungi producing mycotoxins, such as aflatoxin or vomitoxin. Perhaps most important is the omission of costs for chronic illnesses caused by microbial food contamination.[4] Kvenberg and Archer (1987) estimate chronic illnesses occur in 2 to 3 percent of all food-borne infections. The types of illnesses range from arthritis to heart disease to neurological effects to kidney failure. Indeed, the costs of these chronic diseases caused by bacteria and parasites could be relatively much larger than the costs of acute illnesses. For example, Thompson (1986) surveyed rheumatoid arthritis sufferers and asked what they would be willing to pay for an arthritis cure. The answer was an average of 22 percent of household income. This suggests the importance of accounting for costs of chronic, diseases, however, rheumatoid arthritis is likely to be more severe than other likely chronic diseases caused by food contamination.

Other omissions include Harrington and Portney's (1987) other two categories of costs, the disutility of time lost from work or leisure and defensive costs. Both are likely to be significant. Curtin (1984) estimated that the disutility associated with salmonellosis was comparable to the illness costs. Bockstael, Strand, and Hannemann (1987) found that the value of leisure for fishing can be several times greater than the wage rate for people with fixed work schedules. Mauskopf et al. (1988) have estimated salmonellosis costs using indices of health status and their cost estimates are five to nine times greater than reported here (Roberts 1991). In a survey of Kansas consumers, Kramer and Penner (1986) found that consumers are willing to pay 1 to 3 cents per pound more for beef to avoid residues; multiplied by current consumption, thus implies an aggregate willingness to pay is $170 to 500 million. Smallwood (1989) reported a nationwide survey in which over one-half of respondents were willing to pay about 17 cents more per pound for "disease-free" chicken, which would be around a billion dollars. There are no data specifically identifying the time spent on food preparation and sanitation aimed at reducing food-borne illness, although Smallwood (1989) reported that consumers stated they would be willing to spend substantial amounts of time on preparation and sanitation. In a study of a water-borne disease outbreak, Harrington, Krupnick, and Spofford (1991) found the preventive costs to be more significant than the illness costs.

Industry Costs

Todd (1985b) has estimated losses to both food service firms and food processors of food-borne disease outbreaks. In the cases examined, public health officials and the press had informed the public that certain foods had been found to have caused human illnesses. Firms typically recalled specific lots of food. Data from 17 outbreaks and 3 nonillness-

[4]The exception is the Roberts and Frenkel (1990) estimate for congenital toxoplasmosis, which includes the costs of mental retardation.

related recalls revealed processors of food had an average cost of $3 million per outbreak (Todd 1985b). The loss in sales due to product recall and/or plant closure was generally the most significant cost. Also important were laboratory and investigation costs to identify the cause of the outbreak and ill workers who experienced disrupted work schedules and/or were paid disability payments until they were able to resume work.[5] Product liability awards were only occasionally important.

In comparison, costs of a food-borne disease outbreak associated with food service firms were smaller (Todd, 1985a). In 17 incidents, costs averaged just over $100,000 per outbreak. Important categories of costs varied widely, but generally included lost sales, liability suits, and wages paid to ill employees. Because each outbreak is unique, these costs are illustrative of the array of potential costs faced by the food industry. Compared to the billions of dollars in human illness costs estimated to occur annually, these industry costs in the millions of dollars are small.

It is difficult to generalize from these estimates. One could arbitrarily assume that Todd's estimates are representative of all food service outbreaks and multiply the $100,000 cost times the 211 outbreaks reported by the Center for Disease Control (CDC) for "delicatessens, cafeterias or restaurants", for an annual cost estimate of $21 million annually (Bean et al. 1990). Then we could assume that half of the remaining outbreaks (associated with homes or not identified) were caused by processors of food and half were caused by other factors—which would be 135 outbreaks annually multiplied times $3 million, for an estimated aggregate cost of $405 million annually. The total "guesstimate" would be $426 million annually.

Another scenario would be to assume that processors supplying contaminated raw ingredients actually caused ¼ of the food service outbreaks as well as half of the outbreaks associated with homes or not identified. This results in a "guesstimated" total cost of $580 million per year ([53+135] $3 million + [158] $100,000 = $580 million). It is not clear whether either set of assumptions is accurate.

Chronic losses to farmers, food processors, and food service firms are less well recognized, but do occur (Roberts and Todd 1986). At the farm level, chronic costs include increased animal morbidity and mortality and reduced rate of weight gain, as well as costs of human illnesses contracted from infected animals by family members and farm hands. If food processors and food service plants were to buy less contaminated raw product, pay greater attention to personal hygiene, do more time/temperature monitoring, or institute other control procedures, there is the potential for reducing food spoilage, worker illness, and other chronic costs. Chronic costs may be accepted as a cost of doing business when, in fact, many are avoidable.

Types of costs incurred by farmers, food processors, and food service firms in either food-borne disease outbreaks when the food product is identified, or in chronic losses when no such public identification is made, are summarized in Table 2. These costs illustrate the range of potential costs incurred at the farm, processor, and retail level.

Perhaps the costs of defensive or preventive actions taken by industry are larger than costs of the rare food-borne disease outbreak that triggers product recalls and is reported in the press. Roberts and Pinner (1990) surveyed 17 meat processors to determine costs of preventive actions taken to control *Listeria monocytogenes*. Expenses were running at a rate of about $6 million annually and predominantly involved changing plant operations, such as changing production lines, increasing laboratory tests for Listeria, increasing sanitation, and major plant cleanup. While the primary impetus for controlling Listeria was to prevent product recalls or legal suits, most companies identified other economic benefits. Longer product shelf-life was most important, fol-

[5] Food handlers who become contaminated from working with contaminated food often become carriers of the bacteria and have to stop shedding the bacteria before they can go back to work.

Table 2. Industry costs savings of improving food safety

Type of Costs	Farm	Processor	Retailer
Acute Costs Avoided			
Reduced demand for products	X	X	X
Product recall		X	X
Fines		X	X
Investigation costs		X	X
Clean up costs and plant closing		X	X
Liability suits		X	X
Food handler illness	X	X	X
Chronic Costs Avoided			
Mortality of animals	X		
Morbidity of animals	X		
Reduced growth rate	X		
Reduced feed efficiency	X		
Worker illness	X	X	X
Food spoilage losses		X	X
More costly processing techniques		X	X

lowed by reduced product spoilage and lower product returns. Other possible benefits of longer shelf-life—selling meat products in more distant markets, or being able to use cheaper transportation—were considered minimal by the firms.

Public Health Sector Costs

Federal, state, and local agencies of government share responsibilities for regulating and inspecting food. Ongoing federal expenditures are at least $700 million annually (Table 3); however, these are for both microbial and pesticide contamination. The largest share is for the USDA Food Safety and Inspection Service's inspection of meat and poultry. The budgets for the Food and Drug Administration's inspection of all other foods and the EPA's establishment of pesticide tolerances are smaller. Most of these budgeted expenditures go toward defensive or preventive costs, although all three agencies can be involved in a food-borne disease outbreak. Perhaps $300 million is spent on microbial food-borne disease annually by the federal public health sector. State and local costs are unknown.

Summary of Cost Estimates for Microbial Food-borne Disease

The estimates of human illness costs range from $3.7 to $11.4 billion annually for microbial pathogens, although costs for many categories are unknown (Table 4). Industry costs for food-borne disease outbreaks are in the millions of dollars. Federal public health sector expenses are in the millions of dollars and are primarily defensive costs. Defensive costs on the part of consumers and the food industry are also likely to be significant. A rough total for costs which can be estimated ranges from $4.5 to $12.4 billion annually for microbial foodborne pathogens.

Implications for Consumer Demand, Production, and Public Policy

The burden on society of food-borne diseases caused by microorganisms is estimated to be billions of dollars annually, although there is some disagreement as to how many cases of microbial food-borne illness occur annually (Roberts and Foegeding 1991); differing opinions also exist on the best methodology

Table 3. U.S. federal agency food safety responsibilities

Agency	Responsible for	FY 1989 funding (Million $)	FY 1989 staffing (#)
U.S. Dept. of Health & Human Services:			
Food and Drug Administration	Safety of all foods except meat and poultry	132	2,093
	Safety of animal drugs and feeds	26	244
Centers for Disease Control	Investigating food-borne disease problems	n/a	n/a
U.S. Dept. of Agriculture			
Agricultural Marketing Service	Commodity standardization, inspection, and grading	97	2,372
Agricultural Research Service	Scientific food safety research	n/a	n/a
Animal & Plant Health Inspection Service	Protecting animals and plants from diseases and pests	n/a	n/a
Economic Research Service	Economic analysis of food safety problems and control options	n/a	n/a
Federal Grain Inspection Service	Inspecting quality of grain and rice	42	860
Food Safety and Inspection Service	Meat and poultry safety	457	10,399
U.S. Dept. of Commerce:			
National Marine Fisheries Service	Voluntary seafood inspection/grading and research	12	265
Environmental Protection Agency	Establishing pesticide tolerance levels	55	624
Federal Trade Commission	Regulating advertising of food products	n/a	n/a
U.S. Dept. of Treasury:			
U.S. Customs Service	Examining/collecting food import samples for other federal agencies	n/a	n/a
Bureau of Alcohol, Tobacco & Firearms	Regulating production, distribution, and labeling of alcoholic beverages	n/a	n/a

n/a = not available from GAO.

SOURCE: Data from U.S. Government Accounting Office (1991).

Table 4. Annual estimated food-borne disease costs

Type of Cost	Annual Estimates (Billion $)
Consumer Costs	
Acute illnesses:	
Bacterial diseases	3.5-4.8
Parasitic diseases	0.2-6.6
Viral diseases	?
Fungal toxins	?
Chronic illnesses:	
Bacterial diseases	?
Parasitic diseases	?
Viral diseases	?
Fungal toxins	?
Disutility of illness	?
Defensive expenditures	?
Industry Costs	
Outbreak costs	0.4-0.6?
Defensive costs	.1?
Public Health Sector Costs	
Federal	0.3
State	?
Local	?
Total	4.5-12.4+

to estimate costs (Harrington and Portney 1987; Berger et al. 1987; Rice, MacKenzie and Associates 1989; Mauskopf et al. 1988; Landefeld and Seskin 1982; Fisher, Chestnut, and Violette 1989). Estimated social opportunity costs of microbial food-borne illnesses are likely to increase for several reasons:

• Cases of salmonellosis are increasing in most developed countries and the World Health Organization (1991) stated that there has been a "massive rise in food-borne diseases."

• Economists' estimates of the value of food safety are likely to increase as willingness-to-pay measures are increasingly used, since willingness-to-pay estimates are more comprehensive. (Or if cost-of-illness measures are used, and estimates of defensive costs are added, this may also increase the estimates significantly). (See e.g., the costs of giardiasis estimated by Harrington, Krupnick, and Spofford 1991).

• New scientific advances have dramatically increased the number of microbial illnesses known to be caused by contaminated food and we can expect these advances to continue and increase estimates of both acute and chronic food-borne illnesses.

Increasing knowledge about microbial food-borne illnesses and their costs is most likely to affect the demand for meat, poultry, and seafood, since these are the primary carriers of microbial contaminants (Centers for Disease Control 1990). We can expect that the consumption of the highest risk foods, raw or rare animal, or seafood products, might decline. The private sector will then have a clear incentive to develop technologies to produce lower-risk food. For example, Swedish firms are selling "*Salmonella-free*" chicken in Sweden and Denmark.

Advances will continue to be made in risk-assessment methodologies, and the National Academy of Science recommendations on food safety regulation methods are starting to be implemented by USDA's Food Safety and Inspection Service. This will change the nature of food safety regulatory intervention, for example, as the Hazard Analysis at Critical Control Points (HACCP) system is adopted. Economic incentives implicit in regulations could also provide firms with an incentive to provide safer food (van Ravenswaay and Bylenga 1991).

Advances in knowledge about consumer risk perception and valuation placed on these risks will lead to greater understanding of consumer behavior in the marketplace. Consumer groups have put more emphasis on pesticide risks than microbial risks, while food scientists estimate that microbial risks (and particularly bacterial risks) are a greater hazard. Several hypotheses could be explored to probe what facets of food-borne illness concern consumers (Table 5). Until economists do further research and

Table 5. Possible hypotheses to explain the differences between consumers' perceptions and food scientists' estimates of the relative risk from bacterial contamination versus pesticide residues in food

H1:	That consumers are ill informed and do not understand the risk assessments of the food scientists; for example, consumers may think that bacteria only cause stomachaches and may not realize that people also die from bacterial food-borne illnesses. Or it may be that consumers are informed but have a greater "dread" of dying from cancer caused by pesticide residues than dying from salmonellosis.
H2:	That consumers may fee that they can control all bacterial risks by thoroughly cooking meats, poultry, and seafoods whereas they may feel they cannot exert any control (or any significant control) over pesticide residues in food. (In fact, not all bacterial risks can be controlled by cooking, while pesticide residues can often be reduced by peeling produce and sometimes by cooking it.)
H3:	That new risks, such as pesticides, are dreaded more than the older, familiar risks such as bacteria. A corollary is that willingness-to-pay estimates may be appropriate for familiar risks like bacterial contamination of food, but that the willingness-to-accept estimates may be more appropriate for new risks, such as pesticide residues in food.
H4:	That ethics are involved: Consumers believe that farmers and food processors increase profits by using pesticides whereas farm-level control techniques to reduce bacteria do not affect profits.
H5:	That the concern over pesticide residues in food is really a concern for environmental contamination, such as threats to wildlife and contamination of drinking water.
H6:	van Ravenswaay and Hoehn (1991) indicate that results of their contingent valuation study for pesticide residues on food suggest consumers are concerned about the variance of the risk distribution as well as the mean of the risk distribution.

test these hypotheses, we will not know exactly how to interpret the results of willingness-to-pay studies.

As we improve our ability to identify which foods are associated with various risks, we will have the opportunity to refine how risks are communicated for the various food groups. We can expect the method of communicating risk to influence demand. The method of risk communication, the message content, and the format of the message or label can be expected to increase the demand for low-risk foods and decrease the demand for high-risk foods.[6] Two examples of communication of information about food risks that we can expect to see in the United States are

• "These shellfish have been harvested in accordance with strict government sanitation and safety standards. As with some raw food, however, if you suffer from a chronic illness of the liver, stomach, or blood, or have other immune system disorders, you should eat these products cooked." The Interstate Shellfish Commission developed this wording for states requiring point-of-sale messages.

• "Treated by irradiation to control *Salmonella* and *Campylobacter*." A Florida firm has petitioned the Food Safety and Inspection Service in the USDA for permission to irradiate chicken and if permission is granted, their chicken packages could contain labels like this.

Economists will continue to perfect their models of food-borne disease hazards, costs, and defensive action. Extensions of the Harrington and Portney

[6]Currently the Washington State Poultry Commission has prepared cooking instructions for chicken; these appear on the inside of the chicken package and thus do not influence consumer purchases, but can affect cooking and handling. Economists often assume in their models that consumers have perfect information. For this to be true, would information comparing risks per serving by different food groups appear on labels? Or, risks per serving per dollar of food spending? Risks per serving per nutritional density? Or what is perhaps the ultimate, risks per serving per nutritional density per dollar?

(1987) model could include making the health data more realistic by assuming that individuals vary in their susceptibility to various disease severities, and by adding uncertainty so that information about one's risk status and the value of defensive expenditures in reducing the likelihood of illness is uncertain. The sickness equation would then become

Sickness = S(Hazard, Defensive expenditures, Other characteristics)

where other characteristics such as an individual's age, genetics, and health status affect the probability of illness. The decision to engage in defensive expenditures would become more complex:

Defensive expenditures = D(Hazard, Other characteristics, Information)

where the likelihood and amount of defensive expenditures is a function of the hazard, individual characteristics, and information about the hazard.[7]

Health status could be modified to encompass a whole distribution of disease outcomes, instead of a fixed level of sickness, and health status could directly enter the utility function.[8] Until more realistic assumptions are made in the models, the exact relationship between cost-of-illness estimates and willingness-to-pay estimates will remain unclear.

[7]See Barzel (1989) and Griffin (1991) for discussions of the importance of information and transaction costs in welfare analysis.

[8]Berger et al. (1987) do permit health status to enter the utility function, but like Harrington and Portney (1987) they also assume perfect information about food-borne disease causation and effectiveness of defensive actions as well as one fixed disease state rather than a distribution of food-borne disease outcomes.

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