Staff Paper

CONSUMER DEMAND FOR INNOVATION IN FOOD SAFETY

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ABSTRACT

Procedures are identified detecting and estimating consumer willingness to pay for food safety. Case histories demonstrate the significant behavioral response of consumers to changes in food safety. Concepts and methods for estimating willingness to pay for food safety are reviewed. A framework is developed for estimating the impact of food safety on market prices, market quantities, and consumer and producer welfare. Contrary to theoretical models based on zero transactions costs and fully differentiated markets, the empirical results indicate that the welfare losses of a laissez-faire policy to food safety may exceed the losses of direct regulation.

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CONSUMER DEMAND FOR INNOVATIONS IN FOOD SAFETY

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Opinion polls have consistently shown a high level of consumer concern about food safety issues during the last decade, especially about pesticide residues (van Ravenswaay). Food industry and government officials remain uncertain about how best to respond to this concern, largely because they suspect that the concern is based upon inaccurate risk perceptions. While there is some evidence to support this suspicion (Slovic, et al.), it is important to recognize that is little consensus about actual food risks among experts. With technology and information evolving rapidly, food safety choices are going to be made in an environment of limited information, instability, and disagreement over subjective perceptions of risks.

The purpose of this paper is to review research on the consumer demand for innovations in food safety. A first question is whether consumers respond at all to changes in food safety risks. If so, we can then ask what consumers are willing to pay for innovations in food safety and how consumer demand might shift with changes in risk information.

The paper is developed in three sections. We first review several case histories that indicate significant behavioral response of consumers to changes in food safety. We then briefly review the concepts and methods for estimating willingness to pay for food safety.

Using a demand based method, we develop a framework for estimating the impact of food safety on market prices, market quantities, and consumer and producer welfare. The framework is used to estimate the losses stem from parathion residues on plums. Results indicate that the welfare losses of a laissez-faire policy may exceed the losses of direct regulation.

Consumer Response to Food Risks

The literature on willingness to pay for reductions in risks to life is based on the theory that consumers are expected utility maximizers and that utility is contingent on the occurrence of various health outcomes (LIST CITATIONS). Since utility is contingent on the probabilities an individual attaches to different health outcomes associated with various consumption choices, optimal choice depends on an individual's perceptions of those probabilities. Changes in the perceived probabilities may change the optimal consumption bundle and thus the demand for goods.

If this theory is correct, food demand should shift when consumers are presented new information about either exposure to or toxicity of a food chemical. Case studies of such situations support this hypothesis (Brown; Brown and Folsom; Johnson; Shulstad and Stoevener; M. Smith, van Ravenswaay, and Thompson; Swartz and Strand).

Brown studied the effect on the demand for processed cranberries of the 1959 pre-Thanksgiving announcement by the federal government that cranberries contained residues of the herbicide known as amino triazole. Brown hypothesized that news of possible pesticide contamination would have the opposite effect of advertising, and thus demand for cranberries would become more price elastic. Using weekly purchase data from a panel of 300 families in Atlanta collected in the years of 1957 to 1962, Brown was unable to accept the hypothesis of a difference in the price elasticities during those years.

He concluded that the only apparent effect of the event was a temporary shift in demand causing purchases to decline by 26 percent during 1959.

Brown and Folsom examined the effect of 22 outbreaks of gastroenteritis in New York State between May and September 1982 on average weekly prices of hard clams. Quantities of sales were assumed to be unaffected due to fixed supply. A statistically significant drop in price was found during the period of the outbreaks.

Johnson studied the effect of news coverage of EDB insecticide in grain products on monthly sales of dessert, bread, and roll mixes during the period of December 1983 through April 1984. Lost sales were estimated to be between 3.9 to 6.2 percent during the entire period studied with peak declines in sales occurring during peak news coverage periods.

Shulstad and Stoevener studied the effect of news reports of contamination of pheasants from mercury-based fungicides on the annual number of pheasant hunters in Oregon. The news coverage was found to be statistically significant in explaining 92 percent of the decline in the number of hunters from 1970 to 1972.

Swartz and Strand used biweekly data to study the welfare effect of announcements in 1975 of closure the James river oyster beds due to kepone contamination on consumers and producers of oysters in Baltimore markets. Consumer and producer welfare losses were estimated to be 5 percent of the total value of marketings during the news release period. Losses were found to vary with the news release pattern because of the seasonal pattern of oyster consumption. They estimated that consumer and producer losses would have been 25 percent higher if news had been released just prior to a period of peak seasonal demand and 25 percent lower if news had been released prior to a period of low seasonal demand.

M. Smith, van Ravenswaay, and Thompson used monthly data to estimate losses of milk sales during the sixteen months following recalls of milk in Hawaii in 1982 due to heptachlor contamination. Sales were estimated to be off 29 percent from projected levels during the 16 month period, with peak losses occurring in the first few months when news coverage was greatest. Media coverage was found to be significant in explaining sales losses, and the lagged effect of media coverage was estimated to be three months. Sales were approaching normal levels at the end of the 16 month period, but had not yet fully recovered since some milk supplies remained contaminated and media coverage of the event had not yet ended.

In summary, these studies indicate that food demand shifts in response to changes in information about food risks. They also suggest that price elasticity is unaffected by changes in risk information. What we do not know from these studies is what consumers perceived the new food risks to be.

Concepts of Willingness to Pay for Safety

Willingness to pay (WTP) for food safety may be defined in terms of the Hicksian welfare measures. The Hicksian compensating willingness to pay measure is the payment in wealth or income that would leave an individual at an initial level of utility after an improvement in safety.

For a lifetime risk reduction, the compensating WTP measure is defined by maximizing a life cycle utility model to obtain an indirect utility function. Using the indirect utility function, it can be shown a household's WTP is a function,

(1) $$WTP = g(\mathbf{p},\boldsymbol{\Pi},u^0),$$

defined on a vector of market goods prices, **p**, a vector of exogenous risk characteristics, $\boldsymbol{\Pi}$, perceived by a household, and initial utility, u^0. In a general utility model, risk characteristics, $\boldsymbol{\Pi}$, may include a description of the temporal distribution of risk, the distribution of risks across different people in a household, statistical moments of risk probabilities such as means and variances, and elements that describe the severity of outcome (e.g., factors that describe morbidity and mortality).

Most attempts in the applied valuation of risk have been in the areas of workplace and automobile safety. In a typical application, the valuation model is more simple than equation (1). Applications usually focus on a single risk characteristic; a scalar estimate of the probability of death, $\pi \in \boldsymbol{\Pi}$. In place of a household's perceived risk π, the mortality probability is commonly estimated using a biomedical or actuarial model. Applied models tend to ignore the dependence of WTP on prices and initial utility. Also, applied models focus on individual utility and thereby lose a potentially important distinction between collective household risks and risks to the individual. Finally, applications tend to assume that marginal risk valuations are constant within the relevant range.

The restrictions imposed on applied models result in a simple multiplicative model of willingness to pay,

(2) $$WTP = wd\pi$$

where w is average willingness to pay and $d\pi$ is the estimated risk reduction. Given the restrictions, the applied model is most suitable where prices are constant, people are similar as in a trade or profession (e.g., utility), and there is a known consensus regarding risks. In these cases, (2) could be viewed as a linear approximation to equation (1).

Equation (2) facilitates corroboration across different studies. For instance, for mortality risks on the order of 1 in 1000 to 1 in 50,000, Fisher et al find the consensus WTP for a mortality risk reduction of 1 in million ranges from \$1.6 to \$8.5. While this range may seem broad, it is within the order of magnitude bound that is often accepted for the physical parameters of risk estimation.

In considering the application of (2) to food safety, several caveats are in order. First, for food safety risks ranging from nutrition to pesticides residues, there may be no clear consensus regarding risk estimates (e.g., Ames, Magaw, and Gold; Sewell and Whyatt). Individual perceptions differ widely from a biomedical or other technical assessment model. Hammit shows that misuse of technical risk assessments may result in overestimating risk valuations by more than an order of magnitude. Given the lack of consensus on risks, it may be necessary to introduce a measure of dispersion or adopt a Bayesian approach that accounts for learning (Viscusi and O'Connor). Research on subjective risk perceptions should be a component of any systematic research program on food safety.

Second, people may respond to food risks as households rather than as individuals, suggesting that a household production model may be more appropriate. Unlike workplace safety where only a single member of a household may be involved, all members of a household may be exposed to food safety risks. One result is that the age distribution of people within a household may be an important determinant of risk valuations and subsequent precautionary behavior. This determinant is left out of (2). One could imagine that elderly households would respond differently to 30 year cancer risks than households with several small children.

Third, the risk management literature underscores that risk is a multidimensional concept (Slovic). Without an adequate consideration of risk characteristics, risk valuations such as (2) are subject to criticism from within economics and from other disciplines. It seems entirely possible to broaden (2) in the direction of (1) to include the psychologically relevant characteristics of risk.

Methods for Estimating WTP

WTP as stated in (2) requires an estimate of the change in risk, $d\pi$, and an estimate of average willingness to pay, w. Subjective risk perceptions or estimates obtained from a biomedical or actuarial model may be used to characterize $d\pi$.

Demand based methods, the hedonic approach (Rosen), or contingent valuation (Mitchell and Carson, 1989) may be used to estimate average willingness to pay, w. The demand based approach includes a food safety characteristic that shifts demand. Mortality risk due to bacterial content or pesticide residue might be one way to characterize food safety. If (1) these risks vary across different classes of a product such as chicken or plums and (2) consumers are aware of the risks associated with different products, then we would expect the demands for different product classes to shift in a manner consistent with consumers' marginal willingness to pay for risk reduction.

For instance, suppose the inverse demand for a food product can be characterized as a function of the quantity of product purchased, q, and the cancer mortality risk posed by pesticides residues, π,

$$p_q = p(q, \pi, s) \tag{3}$$

where p_q is marginal willingness to pay for the food product and s represents other demand shifters such as income and seasonal effects. A linear approximation to (3) results in

$$p_q = \alpha + \beta q + wd\pi + \gamma s + \epsilon \tag{4}$$

where w again represents consumers' constant marginal willingness to pay for risk reduction.

Two alternatives are possible for estimating the parameters of equation (4). First, given either cross-sectional or times series market data with sufficient variability in prices and risk levels, it would be possible to estimate (4) using ordinary econometric methods. Second, an approximation of (4) could be pieced together from existing studies.

An approximation of (4) could use estimates of α, β, and γ from obtained previous demand research, an estimate of $d\pi$ obtained from a biomedical model, and an estimate of w obtained from existing willingness to pay studies. This eclectic approach is used in the next section to consider the welfare effects of laissez-faire and regulatory approaches to the control of pesticide residues.

The hedonic approach is appropriate when products differ across a large number of characteristics. For instance, the hedonic approach would be appropriate for estimating WTP for risk reduction using a range of meat or vegetable products. With the hedonic approach, products are characterized as a bundle of characteristics rather than as items such as beef, chicken, or pork (Ladd and Suvannunt). Relevant characteristics might include protein content, fat, cholesterol, type of cut, and bacterial count. Characteristics such as cholesterol or bacterial count could be specified in terms of morbidity or mortality probabilities.

The hedonic approach is implemented in two stages. In the first stages, market data is used to regress a cross-section of product prices on product characteristics. The coefficients of the characteristics are interpreted as the market or hedonic price of a characteristics. For small changes in characteristics, these hedonic prices may be interpreted as consumer willingness to pay measures. The second stage of a hedonic analysis uses the estimated hedonic prices and information on consumer characteristics to identify inverse demand functions for the characteristics. Since valid procedures for this second stage remain controversial (Bartik), most hedonic analyses complete only the first stage.

Contingent valuation methods may be used to elicit risk valuations directly from consumers. Contingent methods present respondents with a contingent choice. Contingent valuation uses survey or experimental procedures to confront individuals with choices that are not readily available in existing markets. For instance, the research question might be to value pesticide risk reductions in apples. A questionnaire would be constructed to describe the product's attributes including risk characteristics. Once these attributes are explained, the questionnaire then asks the consumer if he/she would or would not purchase the described product at a specified price. From a sample of such accept and reject responses, limited dependent variable methods can be used to estimated a WTP function.

Well designed contingent valuation studies yield results that are consistent with those of other methods (Mitchell and Carson, 1989). However, the design features of risk valuation questionnaires are still under study. Significant efforts have been made by Hammit; V. Smith, et al; Mitchell and Carson, 1986; and Viscusi and Magat.

While differences in procedures and hypotheses make generalization difficult, the existing contingent valuations of risk underscore the difficult problem of risk communication. Three factors make risk communication problematic. First, as outlined in (1), risk is multidimensional. An accurate description of risk may require a narrative account of event characteristics and probabilities.

Second, people are unfamiliar with the quantitative calculations often used in disciplinary analyses. The questionnaire developed by Mitchell et al spends considerable effort in training people to make quantitative risk tradeoffs.

Third, risk is subjective and value laden. Experts in risk assessment must make value judgements in selecting data, assigned confidence levels, and drawing conclusions. Both experts and lay people may disagree in assessing risks.

Both actual and contingent behavior are affected by these issues in risk communication. However, with contingent valuation, key factors and sensitive issues may be explored and analyzed for their impact on valuation. For instance, contingent valuation can examine the sensitivity of consumer perception to changes in risk information or changes in the way information is communication (V. Smith et al). Moreover, the Bayesian model of Viscusi and O'Connor provides a rigorous, analytical model of analyzing the effects of information. The Bayesian model allows one to estimate the weight that respondents attach to new information provided in a questionnaire relative to their prior risk information.

Policy Analysis and Willingness to Pay

Policy analysis is a primary motivation for research on willingness to pay. Policies may be in either the public or private domain. A public agency may be interested in the net welfare and distributional effects of a regulatory control. A private firm may seek to determine whether the revenues of a pesticide or bacteria free product would justify the costs of developing, advertising, and monitoring the quality of such a product.

In this section, we consider how willingness to pay information might be used to analyze two pesticide residue policies. The following policy setting is assumed. A market for a food product is in an initial equilibrium. At some point in time, research information is released to indicate that routine production procedures leave a pesticide residue in the product that threatens consumer health. Similar to USEPA's pesticide review process, a regulatory agency faces the choice of (1) prohibiting use of the pesticide on the specified product or (2) allowing labeled uses of the pesticide to continue. For simplicity, we refer to the second alternative as a laissez-faire policy since it permits individual consumers the opportunity to evaluate the risks and select an appropriate level of consumption.

If the agency decides to prohibit the pesticide, consumers' perceived pesticide risks will presumably remain unchanged--no risks were initially perceived and the newly perceived risks are eliminated by prohibition. Producers who used the pesticide, however, will experience an increase in production costs once the pesticide is prohibited. The resulting market effects are shown in Figure 1. Consumers' willingness to pay for the product remains at D^0 but the supply curve shifts from S^0 to S^1 with prohibition. Equilibrium price increases from P^0 to P^1 and equilibrium quantity declines from Q^0 to Q^1. The net welfare loss is the shaded area below the demand function and between supply curves S^0 and S^1.

If the agency adopts a laissez-faire policy of inaction, consumers are permitted to make their own decision regarding consumption of the risky product. Efforts to communicate risks may conceivably be carried out by the public agency or private research groups. Recent experience with Alar indicates the effectiveness of private groups in communicated food risks.
With an increase in perceived risks, consumer willingness to pay for the product will decrease. Consumer demand will shift down from D^0 to D^1 as shown in Figure 2. Both equilibrium prices and quantities will decline. The net welfare loss is the shaded area above the supply curve and between the two demand curves D^0 to D^1.

On a priori grounds there is some evidence to suggest that regulatory prohibition may result in larger welfare losses than a laissez-faire policy. For instance, Bockstael shows that in the absence of transactions costs and with full product differentiation, regulation reduces net welfare. The implication for actual policy, however, is not clear. Transactions costs are

Figure 1. Net Welfare Loss with a Regulatory Prohibition

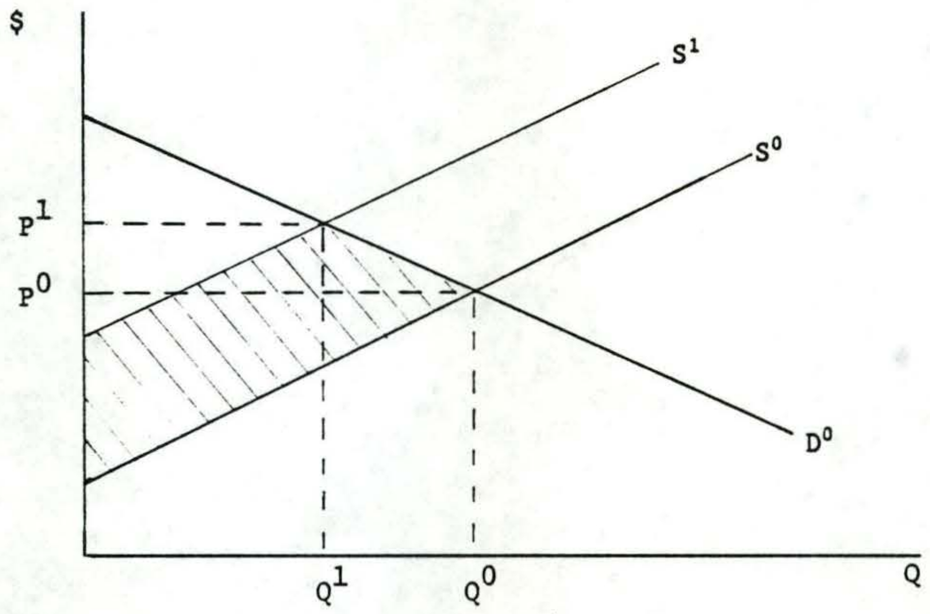
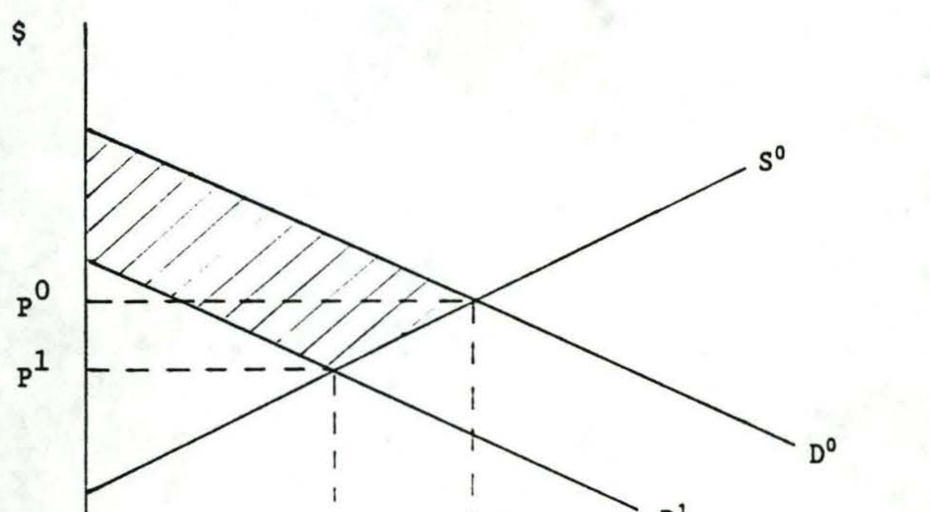


Figure 2. Net Welfare Loss with a Laissez-Faire Policy



not zero and product differentiation is incomplete. Hence, the tradeoff between regulation and laissez-faire is an open empirical question.

The framework we develop parallels the supply side model suggested by Lictenberg et al. The Lichtenberg et al model was developed to examine the first policy alternative, that of regulatory prohibition. Our contribution is to include a risk responsive demand component in order to consider a laissez faire approach to food safety risks.

The framework accounts for three set of actors in a market; producers who use a pesticide that presents health risks to consumers, producers who do not use the pesticide, and consumers. We suppose that up until the point of a regulatory decision, the pesticide is used but there is no evidence to indicate health risks. Supply and demand are therefore in equilibrium where

(5)
$$MC_u(Q_u, s) = P$$
$$MC_n(Q_n) = P$$
$$D(Q_u+Q_n, \pi) = P$$

where MC_u represents the marginal costs of users of a pesticide, s, Q_u is the quantity produced by users, MC_n and Q_n are similarly defined for non-users, and D() is the aggregate, inverse demand for consumers. It is not possible for consumers to distinguish Q_u from Q_n. For notational simplicity, we do not subscript MC_u and MC_n to indicate the marginal costs of the kth producer. However, each producer is assumed to supply product according to the equilibrium condition.

Lichtenberg et al show that the welfare effects of a regulatory prohibition may be estimated using the total differential of an equation system such as (5). This same approach may be applied to a laissez-faire policy that shifts π. To empirically compare the two policies, we consider the case of parathion residues on plums. Information on supply side cost parameters, demand price coefficients, and market quantities are obtained directly from the plums case considered by Lichtenberg et al. To consider the impact of the increased risks associated with a laissez-faire policy, we use the eclectic demand function approach discussed in the previous section. An estimate of $d\pi$ for parathion residues was obtained using an mortality risk assessment model developed by the National Research Council. For w, the literature cited above indicates that consumers are willing to pay between of \$1.6 to \$8.5 for a mortality risk reduction of 1 in a million.

Estimates of the net welfare losses associated with the two policies were estimated using the differential approach discussed by Lichtenberg et al. To examine distributional effects, welfare losses were separately estimated for users, non-users, and consumers. Table 1 gives our loss estimates for direct regulation and laissez-faire.

Each row of Table 1 represents the results of a different policy or different set of parameter values. The first row of Table 1 gives the estimated impacts of the regulatory prohibition of parathion. Regulatory prohibition results in a decline in quantity traded of 39 tons and an increase in price of \$0.18 per ton. The increase in price is offset to users by an increase in marginal costs of \$0.91 per ton. The result is a user producer surplus loss of \$78,600. Non-users gain the price increase without the cost increase so the result in an increase in non-user surplus of \$20,600. While consumers experience no perceived change in safety, they do experience a loss

Table 1. Welfare Impacts of Regulatory Prohibition and Laissez-Faire[a]

Policy	Change Due to Policy					
			Surpluses ($1000)			
	Quantity (tons)	Price ($)	User	Non-User	Consumer	Net
Regulatory Prohibition[b]	-39	0.18	-78.6	20.6	-39.5	-97.5
Laissez-Faire						
WTP = $1.6[c]	-54	-1.13	-38.8	-42.4	-55.4	-137
WTP = $8.5[c]	-289	-1.92	-206	-225	-294	-725

a. Initial equilibrium quantity is 224,250 tons, initial price is $670 per ton, and estimated lifetime risk of parathion residue is 2.49×10^{-8}.

b. Except for non-user surplus, results for the regulatory prohibition are identical to those in Lichtenberg et al. The non-user surplus corrects for an error in the Lichtenberg analysis.

c. Willingness to pay parameter values (WTP) are for a risk reduction of 1 in a million.

of $39,500 in consumer surplus due to higher supply costs. Overall, the net welfare impact is a loss of $97,500.

The second and third rows of Table 1 state the losses accruing to a laissez-faire policy under two sets of parameter assumptions. The second row pertains to a lower bound WTP valuation of $1.6 per 1 in a million risk reduction. The third row pertains to a upper bound WTP valuation of $8.5. Under the laissez-faire approach, both quantities and prices decline with the downward shift in demand. Users, non-users, and consumers all experience surplus losses under the laissez-faire policy. The net welfare loss for the lower bound WTP valuation is about a third greater than the regulatory prohibition. For the upper bound WTP valuation, the laissez-faire welfare loss over seven time larger than the loss due to direct regulation.

It is interesting to note the distribution of losses across user and non-users of parathion. Relative to regulation, the laissez-faire policy under the lower bound WTP assumption reduces non-user surplus by over $62,000. Under the same WTP assumption, the laissez-faire approach increases user surplus by over $40,000 relative to a regulatory prohibition. In all cases, consumers lose but their losses are greatest under the laissez-faire policy.

In summary, the results are quite different from those of theoretical models that assume zero transactions costs and fully differentiated markets. In the case of parathion residues on plums, the net welfare losses favor a policy of direct regulation. Also, both consumers and non-users lose the least under a policy of direct regulation. The policy of greatest gain to pesticide users depends on consumer WTP for risk reduction. If WTP is less than about $3.2 per 1 in a million risk, users would lose less under a laissez faire policy. If WTP exceeds $3.2, all parties are better off with direct regulation.

Conclusions

Knowledge about the presence and toxicity of various substances in food has changed quite dramatically. The presence of a substance can be measured in parts per quadrillion, a level that would have registered as zero on laboratory tests just twenty years ago. Likewise, our ability to examine long term, chronic toxicity is a recent development. The colonies of rats, mice, rabbits and monkeys that are used to in biomedical risk assessment simply did not exist twenty years ago.

Many of the substances widely used in food production, such as pesticides, animal drugs, and preservatives, were registered for use prior to these developments in analytical chemistry and toxicology. We are learning that their residues may be in food, albeit in very small quantities of a part per million or less. We are also learning that these small quantities may potentially pose long-term chronic health risks such as cancer or reproductive toxicity, although there is substantial uncertainty about the risks estimates.

The detection of small mortality risks in food has raised a debate about how much safety consumers want. The results reviewed in this paper indicate, though the risks may seem small, their economic impact is significant. In evaluating policies to control food risks, our analytical framework suggests that research is needed in three areas: (1) on the determinants of consumer risk perceptions, (2) on methods for estimating the costs of risk reduction, and (3) on consumer willingness to pay for reduced food risk.

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