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ECONOMICS OF FOOD AND SAFETY: Risk, Information, and the Demand and Supply of Health

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ABSTRACT

A model of expected utility maximization and a stochastic health production function are used to show how consumer's beliefs, the certainty of beliefs, and the presence of information affects demand for goods as they are driven by the demand for health. Then, it is shown that competitive markets fail to account for the health implications of substances in the production of a commodity that affects health, nor are incentives provided to inform consumers of substance concentrations and its implications to health. This result is shown to not necessarily follow in concentrated industries. Finally, conditions are derived whereby a benevolent government, in the absence of rent seeking, chooses optimal levels of information and taxes to attain Pareto optimal outcomes.

Key words: health, expected utility, government intervention.

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ECONOMICS OF FOOD SAFETY:

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I. Introduction

This paper focuses on the market for substances that affect health. Diet and environmental exposure to substances are becoming increasingly important due to growing demand for better health and an increase in supply of substances that affect health. Important demand factors include the increase in knowledge of health impinging substances, effects of income growth on the demand for health, and the increase in the opportunity cost of time.

Technological advances in the food and medical sciences have increased our understanding of the health implications of diets and substances that are not conducive to health. These advances are clearly changing individual beliefs about factors which impinge on health and preferences for diets that are healthier. Evidence also suggests that health is a luxury good, hence, in the presence of economic growth, welfare will increasingly depend on factors which impinge on health. The income distribution implications of luxury goods are also important since the growth in demand for health care, and a food system which allocates more resources to control dietary exposure to health impinging factors, can create a situation where low income households are priced out of the market for factors which contribute to health.

The rising opportunity cost of time increases the cost of information processing, learning about and searching for consumption bundles that affect health. The cost of time should increase the demand for universal and efficient information systems, particularly as they provide information on the harmful effects of dietary exposures. These costs also tend to increase the demand for food away from home (Senauer, 1979), and hence to increase exposure to a food supply whose dietary implications may be poorly known (Guenther and Chandler, 1981, Morgan and Goungetas, 1986).

Accompanying demand growth is the growth in supply of substances, some of which are known to be harmful to health, while the health implications of others are poorly known. These elements are inherent in the increased fabrication of new foods made possible by advances in technology, such as the sucrose polyesters and, for instance, the increasing array of micro-wave foods from which the possible migration of substances from packaging materials can increase risks to those whose diets tend to be more heavily dependent on these products. Another source of supply related exposures are agricultural chemicals and non-point sources of pollution. Still other sources arise from international trade where problems of equivalent food standards and the possible presence of elements in the food system that emanate from environments outside the jurisdiction of the domestic market create uncertainty as to their health implications. This source of dietary exposure and uncertainty will likely become more important as US imports of fruits, vegetables, beef and specialty foods continue to grow. US exports of pork, poultry and specialty foods will likely face increased scrutiny in foreign markets for the same reasons.

Another dimension of the problem is that competitive market forces alone are unlikely to yield levels of exposure to substances that are Pareto optimal. This market failure problem arises because elements in the food system that impinge on health are, generally speaking, not directly observable. Consequently, knowledge of these elements and their likely health effects are information intensive. However, information is a public good (Stiglitz, 1985) and, if left to competitive market forces, its provision is unlikely to be Pareto optimal.

Markets also tend to fail because many of the harmful substances in the food supply arise from externalities. There is little incentive in a competitive industry to exercises control over harmful substances since they are generally embodied in the attributes, (e.g., pesticide residues) of an otherwise virtually homogeneous product. Much of the primary food supply is characterized by homogeneous products, although, market orders and agreements in the case of dairy, and fruits and vegetables tends to place some control on individual producers. In the case of processed food products that are differentiated from close substitutes, incentives can form to control undesirable substances and to inform consumers of their potential impact on health. However, the level of control exercised and the level and type of information provided consumers may still not be at optimal levels, though they may be Pareto superior to those provided be a competitive industry.

The paper is divided into two main sections. The demand for goods and health when the consumer is uncertain of the mapping from goods to health is presented in the first section. It is shown that the consumer's beliefs, the certainty of beliefs, and the presence of information (signals) are important determinants of demand for goods as they are driven by the demand for health. Having established properties of demand, we focus on market structure as determinants of supply in the second section. It is shown that substances, as attributes to goods, and information are not Pareto optimally supplied in competitive markets. In this sense, competitive markets fail to maximize social welfare. It is shown that concentrated industries have incentives to account for substances that impinge on health, but at high cost to consumers. Finally, we derive conditions whereby a benevolent government, in the absence of rent seeking, chooses optimal levels of information and taxes to attain a Pareto optimal outcome.

II A Model of Health Demand and Risk

Only a few contributions have focused on consumer's behavior under risk and uncertainty (Hanock, 1977 and Pope, 1985), although a number of contributions have considered health as an argument in the utility function, and in one case, the authors estimated a health production function (Pitt and Rowenzweig, 1986). Our approach is to build upon this literature by allowing the consumer to form a Bayesian prior on the health production function which maps goods and services into health.

II.1 Background: health as an argument in the utility function

To illustrate, the consumer derives utility from health H, and from the consumption of other goods and services, y^d. We ignore leisure, medical care and other factors for brevity. The utility function is $U[y^d, H]$, where $U[\cdot]$ is assumed to possess the typical neo-classical properties[2].

The level of health is assumed to be influenced by the mapping $H[y^d]$. Other characteristics that affect health (age, genetic factors, gender, etc.) are treated as exogenous variables, and random variables such as accidents, the occurrence of a virus, etc. are typically treated as being associated with some pdf that eases the estimation of $H[\cdot]$.

Substituting the health production function into the utility function, the utility maximization problem constrained to the income of the household generates demand y^d as a function of price P and income I. This function will contain the parameters of $H[\cdot]$. This optimization problem has the

[2]Brackets are used to denote functions.

property that the marginal utility of income depends not only on the marginal utility of y^d and health but also on the marginal physical product of health production. The demand for health is a derived demand obtained by substituting the demand function for the goods and services that health into $H[\cdot]$. If this approach typifies consumer behavior, then our typical methods for estimating demand function parameters can be exceptionally misleading. For instance, changes in behavior can be attributed to taste when changes are actually do to changes in the exogenous variables in the demand for health.

II.2 Extensions of Model: Risk and Uncertainty

Clearly, the consumer faces numerous sources of uncertainty about the mapping $H[\cdot]$, including its parameters, the person specific characteristics mentioned, incidence of disease and accidents, and the attributes of y^d that affect health. To narrow our the problem to a manageable level, suppose the health production function is defined as:

$$H = ey^d$$

where $e = e[x^1,\epsilon]$ and ϵ is a random variable for which the consumer is assumed to form a subjective expectation[3]. The variable x^1 can be viewed as an input or substance associated with y^d. Hence $e[x^1,\epsilon]$ reflects an attribute of y^d that impacts on health[4]. For ease of exposition, it is useful to view x^1 as the amount of pesticides used in the production of y^d so that $e[x^1,\epsilon]y^d$ captures the pesticide residue and the nutritional implications from consuming y^d.

Drawing upon decision theory, e.g., Marschak and Miyasawa 1968, let:

e	the random variable $e \in E$ that maps the health attributes of food into health
$f_1[e]$	the Household prior pdf over e
s	signals received by the Household giving additional information on $e[x^1,\epsilon]$
$f_2[s]$	pdf over s ($s \in S$), where S is the signal space
$f[e,s]$	joint pdf over e and s

[3]We could have assumed some composite function, e.g., $e[x^1,y^d,\epsilon]$, but this only increases complexity with out providing any additional insights.

[4]See the FASEB report No. FDA 223-84-2059 for a discussion of the methodology and problems of estimating dietary exposures to substances in the food supply.

$g[e|s]$ conditional pdf of e given a particular health signal s

θ vector of moments of $f_1[e]$

γ vector of moments of $g[e[x^1]|s]$.

In the absence of signals, the problem is:

$$\text{(1)} \qquad \underset{\mathcal{X}}{\text{Max:}} \int U[y^d, ey^d] f_1[e] de.$$

$$\mathcal{X} = \{ y^d \in \mathbb{R}_{++} \mid I \geq py^d \}$$

If the constraint is binding, demand functions of the form:

$$y^{do} = y^d[p, \theta, I]$$

$$H^o = F[p, \theta, I] = \int (ey^d[p, \theta, I]) f_1[e] de$$

are implied. This approach is easily extended to account for the value of information (signals, s)[5]. The value of information to the consumer, defined along the lines of Antonovitz and Roe (1988), is briefly sketch in Appendix A. However, since the above framework is too general to draw specific inferences, we select specific structural forms to illustrate the nature of the problem.

Problem A: Affects of y_2^d on health.

Given the distribution of the health attributes, $e_2 \sim N(\bar{e}_2, V[e_2])$, where $e_2 = e_2[x^1, \epsilon]$, consider the consumer's maximization problem:

$$\underset{\mathcal{X}}{\text{Max}} \ E(U) = \int - e^{-\delta y_1^d y_2^d - \delta e_2 y_2^d} f_1[e_2] de_2$$

$$\simeq y_1^d y_2^d + \bar{e}_2 y_2^d - \delta/2((y_2^d)^2 \, V[e_2]),$$

$$\text{(2)} \qquad \mathcal{X} = \{y_1^d, y_2^d \in R_+ \mid I \geq p_1 y_1^d + p_2 y_2^d \}$$

where y_i^d , I, and p_i denote goods, income and prices, respectively. Note that the utility function resembles the constant absolute risk form commonly assumed in portfolio problems.

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[5] A discussion of the economics of information in consumer markets is given by Ippolito, 1988. For a conceptual treatment, see Kihlstrom, 1974 and Hess, 1982.

Proposition A.1: Demand functions of this system are as follow[6]:

$$y_1^{d*} = \frac{I(p_2 + p_1\delta \bar{V}[e_2]) - p_1 p_2 \bar{e}_2}{2p_2 p_1 + p_1^2 \delta V[e_2]} \; ; \qquad y_2^{d*} = \frac{I + p_1 \bar{e}_2}{2p_2 + p_1 \delta V[e_2]} .$$

This result is obtained using the familiar LaGrange method. The constraint is binding since the objective function is non-decreasing in y_1^d.

Remarks A.1: Key results are:

i) It is easily shown that the demand functions in the absence of health are $y_1^{d*}=I/2p_1$, $y_2^{d*}=I/2p_2$;

ii) It is clear that prior beliefs and variance of health attributes are important explanatory variables;

iii) Risk averse attitudes (δ) are inversely related to the consumption of the good affected by health attributes. The quantity of y_2^d demanded decreases as the consumer's aversion to risk increases.

iv) If an individual is risk averse, a mean preserving increase in the variance of $\bar{e}_2$ decreases the quantity of y_2^d consumed, while an increase in the mean $\bar{e}_2$ (e.g., less pesticide residues) increases its consumption.

v) Roy's Identity holds.

Proposition A.2: Both demands are downward-sloping in own price,

$$\frac{\partial y_1^{d*}}{\partial p_1} = \frac{-(I(2p_2^2 + 2\delta p_1 p_2 V[e_2] + (\delta p_1 V[e_2])^2) - \delta p_1^2 p_2 \bar{e}_2 V[e_2])}{p_1^2(2p_2 + p_1 \delta V[e_2])^2} < 0,$$

if $I(\cdot) > \delta p_1^2 p_2 \bar{e}_2 V[e_2]$, and

$$\frac{\partial y_2^{d*}}{\partial p_2} = \frac{-2(I + p_1 \bar{e}_2)}{(2p_2 + p_1 \delta V[e_2])^2} < 0.$$

It also follows that $\partial y_i^d/\partial p_j \neq \partial y_j^d/\partial p_i$, and $\partial y_i^d/\partial I > 0$. Theincome elasticity of demand for $y_1^d > 1$ and for $y_2^d < 1$.

Proposition A.3: Comparative statics of this system with respect to p_1 are:

$$\frac{dy_1^d}{dp_1} = \frac{-[(p_2+p_1\delta V[e_2])y_1^d + \lambda p_2^2]}{A} < 0; \quad \frac{dy_2^d}{dp_1} = \frac{p_1 p_2 \lambda - y_1^d p_1}{A}$$

[6]Since the health production function assumed here is of a simple form, the results stated for demand apply directly to health.

$$\frac{d\lambda}{dp_1} = \frac{-(p_2 + p_1\delta V[e_2])\ \lambda}{A} - \frac{y_1^d}{A} < 0,$$

where, $A = 2p_1p_2 + p_1^2\delta V[e] > 0$ and λ is the LaGrange multiplier. The conditions for p_2 are similar. The proof follows from total differentiation of the first order conditions and the application of Cramer's rule.

Remarks A.3: The signs of the changes are similar to those of non-risk system, but their magnitudes are different of course. Complementaries are possible between the two goods. Note also that certainty of beliefs, $V[e]$, affect the marginal utility of income.

Problem B: Problem A in the presence of signals.

In this situation we assume that the consumer has access to a signal s at no cost and that the joint distribution $f[e_2,s]$ is defined by $(e_2,s) \sim N(\bar{e}_2,\bar{s},\Sigma)$. The maximization problem is :

$$\underset{Y}{\text{Max}}\ E(U) = \int -e^{-\delta y_1^d y_2^d - \delta e_2 y_2^d} g[e_2|s]de_2$$

$$\simeq y_1^d y_2^d + y_2^d(\bar{e}_2 + C(s - \bar{s})/V[s]) - \delta/2\{(y_2^d)^2(V[e_2] - C^2/V[s])\}$$

subject to the budget constraint, where $C \equiv E(e_2 s) - \bar{e}\bar{s}$ and E is the expectations operator.[7]

Proposition B.1: The maximization problem yields the following demand functions:

$$y_1^{d*} = \frac{I(p_2 + p_1\delta(V[e_2] - C^2/V[s])) - p_1p_2(\bar{e}_2 + C(s - \bar{s})/V[s])}{2p_2p_1 + p_1^2\delta(V[e_2] - C^2/V[s])}$$

$$y_2^{d*} = \frac{I + p_1(\bar{e}_2 + C(s - \bar{s})/V[s])}{2p_2 + p_1\delta(V[e^2] - C\ /V[s])}.$$

Remarks B.1: Key results are:

i) If $(s - \bar{s}) \geq 0$, then the propositions for problem A hold in the presence of signals.

ii) If e_2 and s are independent, $C = 0$, the analytical results of

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[7]See Chapter 9 in DeGroot (1970) for the derivation of conditional expected values of this type.

problem A are obtained since the signals provide no information, otherwise they serve to decrease variance,

iii) Signal s could be advertising, or information provided by the government. If s reduces variance, (as would be expected for a large number of trials) the marginal utility of income also increase.

The results of this section serve to establish that consumer's beliefs, the certainty of these beliefs and the presence of signals can affect choices. However, as is typically the case in production theory too, the form of the agent's utility function is an important determinant of the results obtained.

Problem C: Satiation is possible.

Consider the problem

$$\max_{X} E(U) = -\left(e^{-\delta(y_1^d + y_2^d)} \int e^{-\delta e_1 y_1^d} f_1[e_1]de_1 \int e^{-\delta e_2 y_2^d} f_1[e_2]de_2\right)$$

$$\simeq (y_1^d + y_2^d + \bar{e}_1 y_1^d + \bar{e}_2 y_2^d - \delta/2\{(y_1^d)^2 V[e_1] + (y_2^d)^2 V[e_2]\}$$

subject to (2), where health is affected by both goods, $H = e_1 y_1^d + e_2 y_2^d$, and the e_i are independent and distributed $N(\bar{e}_i, V[e_i])$.

Proposition C.1: When (2) is binding, the demand system is:

$$y_i^d = \frac{I\delta V[e_j]p_i + p_j^2(1 + \bar{e}_i) - p_j p_i(1 + \bar{e}_j)}{\delta(V[e_j]p_i^2 + V[e_i]p_j^2)}, \quad i,j = 1,2$$

and when (2) is non binding, the system is:

$$y_i^d = (1 + \bar{e}_i) / \delta V[e_i].$$

This example illustrates the case of a risk averse individual where it is possible for only utility function parameters to be determinants of consumption levels.

III THE SUPPLY OF SUBSTANCES AFFECTING HEALTH

In this section, we consider the incentives an industry might have to respond to consumer's concern about substances that impinge on health, and how a government might devise policy to alter consumer beliefs and provide market incentives to guide an industry to the provision of healthier food. Our approach is to construct, essentially, two simple and abstract models of an industry supplying a good that has health implications.

III.1 The Perfectly Competitive Industry

Let the supply function of an individual firm producing the good y in a competitive industry be denoted as $y[p,c]$ where c is a vector of prices of the variable factors x employed in the production process $f[x]$ which is monotonic, increasing and quasi-concave in x. Let the first element x_1 of x be the input which has health implications in the production of y. In the spirit of the previous section, let x_1 denote the amount of pesticide applied to the production of y with the result that pesticide residues affect the healthy attribute (residue free food) of the good consumed. As the concentration of residues *increase*, the producer expects the desirable attribute, e.g., the percentage of the product that is free of residues, to *decrease* and, if consumed, a deterioration in health is expected to result according to $e[x_1,\epsilon]y$, i.e.,

$$\partial H/\partial x_1 = \int((\partial e[x_1,\epsilon]/\partial x_1)y + e[x_1,\epsilon]\partial f[x]/\partial x_1)g(e|s)de < 0$$

is assumed. Hence, as pesticide inputs increase, residues increase with the result that health deteriorates ($\partial\bar{e}/\partial x_1 < 0$) and y increases by $\partial f[x]/\partial x_1$. We assume diminishing returns to x_1 in the production of health as it is decreased. If all N firms in the industry are identical, then health produced is:[8]

$$Na = e[X_1,\epsilon]Y^s = e[Nx_1,\epsilon]Ny.$$

Finally, we assume that producers hold the same beliefs as consumers.

Let the individual demand function be given by

$$y^d = y^d[p,\gamma,I],$$

where, in the spirit of the previous section, the mean $\bar{e}$ and variance $V[e,s]$ are sufficient to describe the consumer's <u>beliefs</u> of the implications of the residual contaminant in food consumed, $\gamma = (\bar{e}[x^1,\bar{\epsilon}],V[e[x^1,\epsilon],s])$, x^1 is the amount of pesticide used to produce the food the individual consumer ingested, and I denotes disposable income. We suppress the prices of other commodities to minimize notational clutter.

We make the further simplifying assumption that all consumers are identical, so that industry demand is given by

$$Y^d = Y^d[p,\Gamma,I] \tag{3}$$

where $\Gamma = (\bar{e}[X^1,\bar{\epsilon}],V[e[X^1,\epsilon],s])$. Hence, health supply and demand is $e[X_1,\epsilon]Y^s$ and $e[X^1,\epsilon]Y^d[p,\Gamma,I]$, respectively, where $X_1 = X^1$ when markets for

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[8] Problems of aggregating $e[\cdot]$ over N are firms are ignored.

Y clear at a unique price.

In a competitive industry, there is no incentive for the individual producer to alter his allocation of x_1 since these allocations have no noticeable impact on X_1, or p. Also, the individual producer would be unwilling to incur costs to advertise, i.e., to provide signals, because signals would either have no noticeable impact on aggregate beliefs, or if they did, the benefits would be shared by the industry. This is the classic case of a market imperfection.

This problem is partially depicted in Figure 1 where we ignore the variance effects of e on demand. Price appears on the vertical axis, attribute $\bar{e}$ on the facing horizontal axis and, partially obstructed form view, good Y on the other horizontal axis.

The supply curve for a competitive industry is denoted by the line segment from the origin to point H, along which levels of pesticides and other inputs are combined in a least cost combination. Market demand is denoted by the *plain* A. In a competitive industry, the market clears at point D since individual firms have no incentive to alter x_1 from its least cost combination. If x_1 *where* altered from its least cost combination, the cost of producing a given level of y would obviously increase. The locus of points along GDF are points where demand for Y equals its supply for various levels of X_1. Hence, from point D through F, costs increase as x_1 is *decreased* from its least cost combination with other inputs, and the desirable attribute $\bar{e}$ increases. Because the desirable attribute increases, demand also increases along the points DF; demand decreases as x_1 is *increased* from its least cost combination with other inputs along DG. Effectively, increased demand (points DF) is "purchased" at higher production costs. In the absence of a producer's association or some central authority, firms in a competitive industry have no incentive to produce along DF. Of course, competition from close substitutes in consumption can lower the amount of the good consumed and hence the harmful substance.

III.2 A Single Firm Industry

Consider the other extreme where the industry is characterized by a single producer who, for what ever reason, chooses production levels by setting marginal cost equal to price using a technology that is monotonic, increasing and quasi-concave in factor inputs x[9]. However, we show that the monopolist has incentive to discriminate in allocating the input X_1 that gives rise to harmful substance in food and in the provision of information. In this case, the monopolist can influence the demand facing the firm through its choice of X_1 and signals s. An increase in demand, and profits, are "bought" at an increase in production costs.

To see the monopolist's problem, refer to Figure 1, where B is the marginal revenue *plain*. The B plain intersects the demand plain A for reasons made apparent below. The locus of points EC are the intersection of the marginal revenue plain and the supply function. The locus of points also denote alternative combinations of quantities of output Y^S and attributes $\bar{e}$ for which marginal revenue equals marginal cost (supply). As the monopolist changes allocations of X_1 from the least cost combination of inputs, total costs increase for a given level of output Y^S. Hence, the supply surface is convex.

Typically, the monopolist would prefer the least cost combination of inputs along the origin through point H. However, while changing the least cost level of X_1 increases costs, it also alters or "shifts" demand. Effectively, the monopolist "buys" changes in demand with an increase in cost from allocating a non least cost combination of inputs.

More formally, using (3), let the price inverse demand function be denoted as: $p^d = p^d[Y^d, \Gamma, I]$. The monopolist's profit maximization problem is:[10]

$$\text{P1:}\quad \underset{\mathcal{X}}{\text{Max}} \qquad p^d[f[X_1],\Gamma,I]f[X] - cX - rs$$

$$\mathcal{X} = \{X,s \in \mathbb{R}_+\}$$

where s denotes information (advertising, signals) that the monopolist obtains at unit cost r.

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[9]Our intent is to abstract from behavior which discriminates over price and instead focuses on health.

[10]If the monopolist was also a price discriminator, condition (4.1) would become: $p^d_{Y^d} f_{x_1} f[X] + p^d f_{x_1} = c_1 - (p^d_{\bar{e}} \bar{e}_{x_1} + p^d_v V_e e_{x_1}) f[X]$,

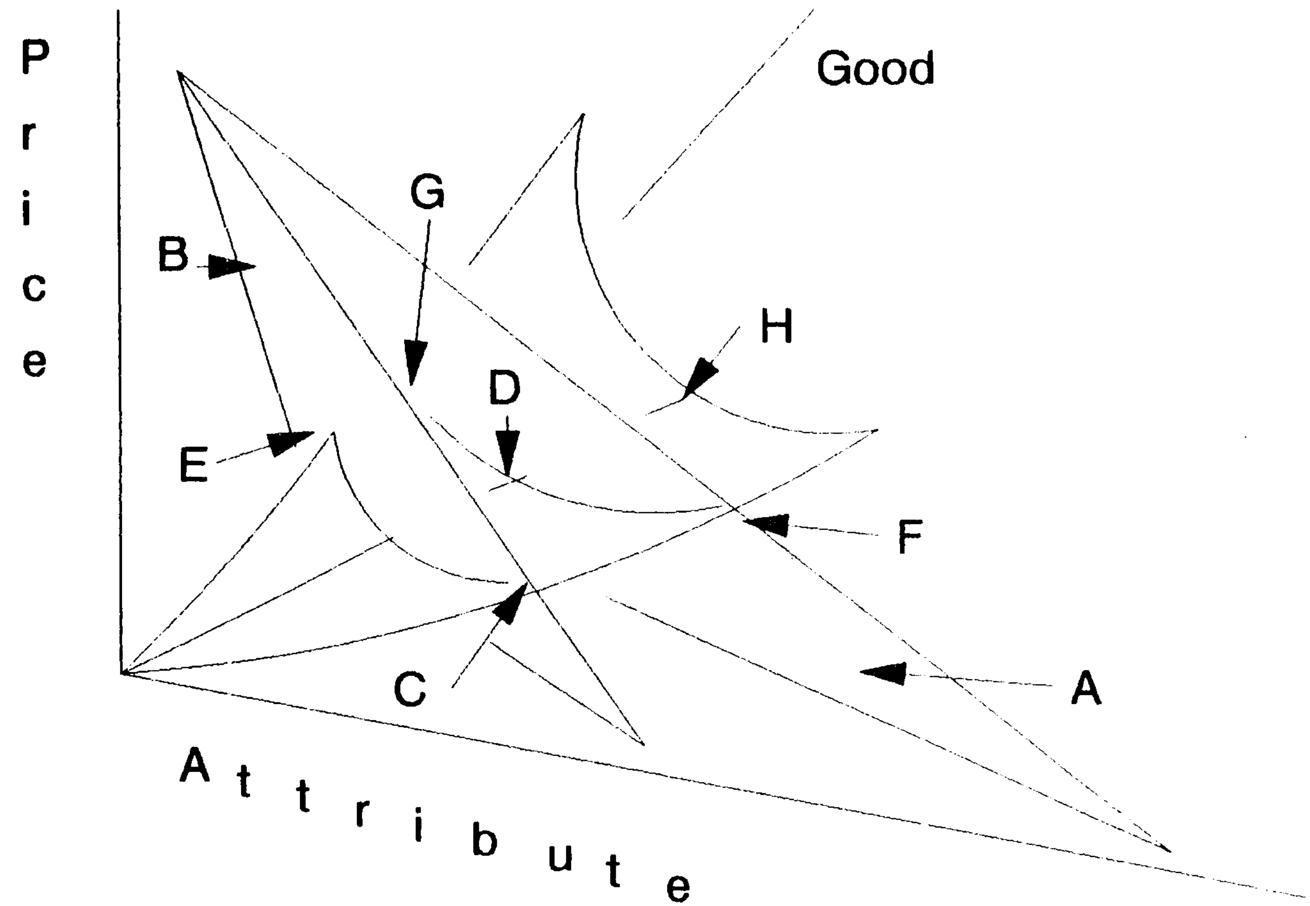

Figure 1: Demand And Supply For Food And Attributes

Proposition A.P1: Under plausible conditions, the monopolist described in P1 chooses levels of inputs X and information levels s according to the following conditions:

(4.1) $p^d f_{x_1} = c_1 - (p^d_{\bar{e}}\, \bar{e}_{x_1} + p^d_V\, V_e\, e_{x_1}) f[X],$

(4.2) $p^d f_{x_i} = c_i,\ i = 2, \cdots, m.$

(4.3) $p^d_V\, V_s\, f[X] = r.$

These results follow when P1 is quasi-concave in X so that the first order conditions are both necessary and sufficient.

Remarks: The term $p_{\bar{e}}\bar{e}_{x_1}$ is negative since an increase in the mean levels of pesticide residues decrease the quantity demanded for reasons mentioned. Ignoring variance, it can be seen from Figure 1 that production would occur some where on the line segment C to the least cost combination of inputs, since, from the least cost combination to E, marginal costs increase and the "wedge" between marginal revenue and price *decreases*. According to our diagram, excess profits are zero at E. For intersection of plain A and B, we require that $\bar{e}_{x_1}$ equal zero, i.e.,that the food ingested becomes saturated with residues so that additional pesticides allocated to production have no additional impact on the attribute. If this were not the case, the plains would converge but not intersect as appears; our results would not be altered of course. Thus, we can see that some improvement in the consumer's health would result in the case of a single firm industry. Note however, that the consumer is paying dearly for this improvement. The amount paid is equal to a vertical line from point, say C, to plain A. These are the monopolist's excess profits for the case where we ignore variance and the supply of signals s.

For reasons mentioned, $p_V\, V_e\, e_{x_1}$ is negative since the three terms are expected to be negative for an increase in x_1. In the case of (4.3), V_s is negative when an increase in information reduces consumer's uncertainty of the food residue and hence its health implications. It is possible of course that the consumer is uninformed so that additional information causes an awareness of the health implications and increases perceived variance, in which case the monopolist would attempt to leave the consumer uninformed. However, after a period of time, and as a Bayesian, additional information should reduce uncertainty. In this case, the monopolist provides information to equate its marginal value product of providing signals,

$p_v V_s f[X]$, to marginal cost r.

In principle, the monopolist does not know the consumers beliefs for sure. Hence, the monopolist's problem might be better specified if account was taken of the monopolists expectations of the consumer's beliefs of the mapping from $e[X_1,\epsilon]$ to health. Then, to the monopolist, p would be a random variable. Taking account of price risk could cause a risk averse monopolist to over or under allocate inputs and advertising s depending on whether these inputs, and advertising in particular, are risk increasing or decreasing. We leave the analysis of this problem to another paper.

The non-price discriminating monopolist depicted here could also be considered as a producer's association which makes a collective choice and then imposes that choice on individual producers. However, in this case, consideration would need to be given to how penalties and bonuses would be given to those who meet the guidelines derived as an optimization to P1.

Now, return to the perfectly competitive industry, and consider the role of a government that is willing to address the market failure problem.

III.3 The Role Of Government In The Presence Of Market Failure

Government's policy instruments are signals (s) made available to consumers regarding the health affects of the substance and a tax (t) placed on the price of the input that harms health. Hence, input price becomes $c_1'(1+t)$ where c_1' is the supplier's price. To assure that the government does not run a fiscal deficit or surplus, consumers receive a lump sum income transfer so that disposable income I is equal to their initial endowment K plus the transfer, i.e.,

$$I = K - rs + c_1' t X_1.$$

The nature of this problem can also be seen by referring to Figure 1. It was mentioned that point D is market equilibrium in a competitive industry. The problem for the government, ignoring variance and signals, is to find some point along DF that maximizes total welfare and to be able to induce producers to produce at that level. Segment DG would not be of interest since costs rise while demand falls. A point along DF is obviously Pareto Superior to points on DG.

First, we construct the industry's general equilibrium profit function. We take as given the community's expected indirect utility function derived from identical consumers that hold preferences and have access to signals of the type presented in problem B of the previous section.[11] Then, we posit a government welfare function that, in the absence of rent seeking, weights equally the utility of consumers and producers.

If markets clear at a unique price, then from, $Y^d[p,\Gamma,I] = Y^s[p,c]$, we obtain $p = p[\Gamma,I,c]$. Recall that $\Gamma = (\bar{e}[X_1,\bar{\epsilon}],V[e[X_1,\epsilon],s)$. The industry's indirect profit function is $\Pi[p[\Gamma,I,c],c]$. From the envelope theorem, $\Pi_{c_i} = - X_i[p[\Gamma,I,c],c]$. That X_1 appears as an argument in $X_1[\cdot]$ indicates that this is not reduced form factor demands. Solving for X_1 yields the reduced form $X_1 = X_1^*[r,K,s,c]$. The equilibrium price now becomes $p = p[\Gamma^*,I,c]$, where $\Gamma^* = (\bar{e}[X_1^*,\bar{\epsilon}],V[e[X_1^*,\epsilon],s])$ and $I = K - rs + c_1'tX_1^*$. The industry's profit function can now be stated as $\Pi[p[\Gamma^*,I,c],c]$.

Let $U(p[\Gamma^*,I,c],\Gamma^*,I)$ and $\mathcal{U}(\Pi[p[\Gamma^*,I,c],c])$ denote the community's expected indirect utility function and the industry's utility of profit function respectively[12]. Given this knowledge, the government is assumed to choose signals s and taxes t as though it sought to maximize the social welfare function:

$$\text{P2:} \quad \max_{\mathbb{Z}} Z = \Lambda_1\{ U(p[\Gamma^*,I,c],\Gamma^*,I)\} + \Lambda_2\{ \mathcal{U}(\Pi[p[\Gamma^*,I,c],c])\}$$

$$\mathbb{Z} = \{s,t \in \mathbb{R}_+\}$$

formed from its preferences over the welfare of consumers and producers, where Λ_i are its preference parameters.

Proposition A.P2: The government chooses signals s and taxes t to equate the communities expected marginal gain from the provision of information s and the reduction in input use X_1 to their respective marginal costs, i.e.,

$$(5.1) \qquad \partial Z/\partial s = \{U_{\bar{e}}\,\bar{e}_{x_1}X_{1s}^* + U_v(V_e e_{x_1}X_{1s}^* + V_s)\}/U_I - r + c_1'tX_{1s}^* = 0$$

$$(5.2) \qquad \partial Z/\partial t = \{U_{\bar{e}}\bar{e}_{x_1} + U_v(V_e\, e_{x_1})\}/U_I + tc_1' = 0,$$

The sketch of the proof appears in Appendix B.

Remarks: For the case where additional information leads to a reduction

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[11]An alternative to the community function is to specify individual expected indirect utility functions for each of n individuals, $n = 1,\cdots,N$.

[12]If individual utility functions are used, then the first component of P2 would be $\sum_n^N \Lambda_n U_n[p[\Gamma^*,I,c],\Gamma^*,I]]$. If consumers are identical, the results are the same as those obtained here.

in the harmful input X_1, we expect: $U_{\bar{e}} > 0$, $\bar{e}_{X_1} < 0$, $V_e < 0$, $X^*_{1s} < 0$, $U_V < 0$, and $V_s < 0$. Hence, in (5.1), the term in $\{\cdot\}$ is positive and in (5.2), the term in $\{\cdot\}$ is negative. The expected marginal utility of income U_I, is akin to a price index, it converts the terms in $\{\cdot\}$ to values. Thus, these conditions are of the form: marginal cost, $r + tc_1'$, equals marginal returns. The first term in $\{\cdot\}$ is the change in marginal utility due to a change in the level of the attribute. The ratio U_V/U_I corresponds to the risk evaluation differential quotient in production theory where it measures the slope of an isoutility curve in mean-variance profit space[13]. In our case, it corresponds to the individual's level of risk aversion as measured by δ in the problems presented in Section II.2. If the affect of signals is to alter variance alone, then the change, X^*_{1s}, is likely to be small because it captures the secondary effects of changes in market equilibrium from demand shifts associated with changes in variance and disposable income required to pay for government's cost of providing signals, rs. In this case, condition (5.1) reduces to setting the cost r of producing signals to the "marginal" risk premium $U_V V_s/U_I$.

Given our assumptions regarding the signs of the partial derivatives, condition (5.2) implies that t is not negative. Hence, firms are induced to reduce their use of X_1. If new information (signals) reduce X_1, then there is a tendency to supply less information since $c_1' t X^*_{1s}$ is negative and there is less of the harmful substance consumed. If information results in an increase in the use of X_1, then there is a tendency to supply more information since consumption of the harmful substance increases. Since $Y^d = Y^s$, these conditions also characterize an equilibrium.

IV SUMMARY REMARKS

Exposure to substances that impinge on health are becoming increasingly important due to the growth in demand for better health and an increase in the supply of substances that affect health. Building upon other approaches that treat health as an argument in the consumer's utility function, a conceptual framework is developed to provide insights into how consumer's beliefs, the certainty of beliefs, and the presence of information (signals) affects demand for goods as they are driven by the demand for health. Effectively, using a neo-classical model of expected utility maximization,

[13] See Magnusson for a discussion of this measure of risk aversion in production theory.

food safety is cast into a consumer's perception of the effects that dietary exposure to substances have on health and how information might change these views. It is shown that this approach alters our traditional views of consumer demand behavior and it provides insights into how market structure and policy instruments might be used to improve health and consumer welfare.

It is shown that competitive markets are unlikely to take into account the health implications of substances in the production of a commodity that affect health, nor is there likely to be an incentive for them to inform consumers of substance concentrations and its implications to health. In this sense, competitive markets fail to maximize social welfare. This result does not necessarily follow in concentrated industries, although these industries may extract excessive rewards for the gain in health attained. Finally, we derive conditions whereby a benevolent government, in the absence of rent seeking, chooses optimal levels of information and taxes to attain Pareto optimal outcomes. The optimal level of instruments depend on consumer perceptions of the affects of substances on health, the level of risk aversion, and, for supply, on the marginal productivity of the substance, e.g., pesticides, used in the production of goods consumed. Technological change, financed from tax receipts imposed on the harmful input that alters these harmful effects, either through substitute inputs or substitute goods, would likely yield Pareto superior outcomes.

APPENDIX A: Value of Information

Measures of the value of information depend on whether a signal is observed before a choice is made or whether the signal is also uncertain. Accordingly, we define the following situations.

Situation 1, prior information only: In the absence of signals, let $y^{do} = y^d[p,\theta,I]$ denote the value which maximizes the indirect expected utility function:

(A,1) $$E[u] = \int u[p,\theta,I,e]f_1[e]de \equiv \int u[y^{do}, ey^{do}]f_1[e]de \equiv \underset{X}{\text{Max}} \int u[y^d, ey^d]f_1[e]de.$$

subject to (2) binding.[14]

Situation 2, the presence of signals: When signals are available, and uncertainty exists as to which signal will be received, let $y^{d*} = y^d[p,\gamma,I;s]$ denote the result from a solution to the problem:

(A.2) $$E[u] = \iint u[p,\gamma,I,e;s]g[e|s]f_1[e]deds \equiv \int f_2[s]\{\int u[y^{d*}, ey^{d*}]g[e|s]de\}ds \equiv \int f_2[s]\{\underset{X}{\text{Max}} \int u[y^d, ey^d]g[e|s]de\}ds.$$

subject to (2) binding.

Situation 3, given a signal: Suppose an individual observes a signal $\bar{s}$. Let $\bar{y}^d = y^d[p,\gamma,I;\bar{s}]$ denote the result from a solution to the problem:

(A.3) $$E[u]=\int u[p,\gamma,I,e;\bar{s}]g[e|\bar{s}]de \equiv \int u[\bar{y}^d, e\bar{y}^d]g[e|\bar{s}]de \equiv \underset{X}{\text{Max}} \int u[y^d, ey^d]g[e|\bar{s}]de.$$

subject to (2) binding.

The ex-ante value of information, say VI_1, is determined from equations (A.1) and (A.2):

$$\iint u[p,\gamma,(I - VI_1),e;s]g[e|s]f_1[e]deds = \int u[p,\theta,I,e]f_1[e]de.$$

If signal $\bar{s}$is obtained but health attributes are still unknown, the "quasi" ex-ante value of information , VI_2, is defined by equations (A.1) and (A.3) where the exception operator for (A.1) is based on the information embodied in the signal, given the choice y^{do}:

$$\int u[p,\gamma,(I - VI_2),e;\bar{s}]g[e|\bar{s}]de = \int u[p,\theta,I,e]g[e|\bar{s}]de.$$

This measure is referred to as quasi ex ante because the consumer has received a particular signal but does not know exactly which event will occur[15].

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[14]For convenience, consider y^d as a composite good.

[15]These values are easily derived for the utility functions presented in the

APPENDIX B: Proof to Proposition A.P2

The FOC are:

$$\partial Z/\partial s = \Lambda_1\{(U_p(p_{\Gamma*}\Gamma^*_s + p_I I_s) + U_{\Gamma*}\Gamma^*_s + U_I I_s\ )\} +$$

$$\Lambda_2\{U_\Pi(\Pi_p(p_{\Gamma*}\Gamma^*_s + p_I I_s)F[X*] + \Sigma_i(p[\cdot]F_i X^*_{is}\ - c_i X^*_{is}\ )\} \leq 0.$$

$$\partial Z/\partial t = \Lambda_1\{(U_p(p_{\Gamma*}\Gamma^*_t + p_I I_t) + U_{\Gamma*}\Gamma^*_t + U_I I_t\ )\} +$$

$$\Lambda_2 U_\Pi\{(\Pi_p(p_{\Gamma*}\Gamma^*_t + p_I I_t)F[X*] + \Sigma_i(p[\cdot]F_i X^*_{it}\ - c_i X^*_{it}\ ) - c'_1 X^*_1\} \leq 0.$$

Assuming the Negishi (1960) condition, $\Lambda_1 = 1/U_I$, and $\Lambda_2 = 1/U_\Pi$, for an interior solution, and using $U_p/U_I = -Y^d$, these conditions reduce to:

$$\partial Z/\partial s = \{U_{\bar{e}}\ \bar{e}_{x_1} X^*_{1s} + U_v(V_e e_{x_1} X^*_{1s} + V_s)\}/U_I - r + c'_1 t X^*_{1s}$$

$$\partial Z/\partial t = -\{U_{\bar{e}}\ \bar{e}_{x_1} + U_v V_e e_{x_1}\}/U_I + c'_1 t$$

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previous section.

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